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The CD futures market: hedging and price discovery performance

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THE CD FUTURES MARKET: HEDGING AND PRICE DISCOVERY PERFORMANCE

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The CD futures market: Hedging and price discovery performance

by

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CHAPTER I. INTRODUCTION

Futures markets ordinarily perform two economic functions; they facilitate the transfer of risk from those who do not want it to those who are more willing to accept it, and they provide price discovery signals to the public.

Futures markets are generally associated with agricultural commodities such as corn or soybeans. In recent years, however, futures contracts have been developed for financial instruments as well. Today, futures contracts exist for Treasury Bills, Treasury Bonds, Treasury Notes, GNMA certificates, and Certificates of Deposit. Contracts for Municipal Bonds and Federal Funds are awaiting regulatory approval.

The establishment and growth of these markets have generated considerable controversy. Froewiss (1978) noted the concern of some segments of the financial press that speculative trading of financial futures might increase the volatility of spot securities prices (Business Week 1977a, b). A joint study by the staffs of the U.S. Treasury and Federal Reserve System (1979a, 1979b) expressed concern that the existence of financial futures might complicate Treasury debt management or Federal Reserve open market operations.

The controversy surrounding these markets has focused attention on their regulation. The Commodity Futures Trading Commission (CFTC) is responsible for regulation of all U.S. futures markets. Under the

Commodity Futures Trading Commission Act of 1974, CFTC approval is required before trading can commence in any futures contract. A contract is denied approval only if it can be demonstrated that trading would be contrary to the public interest. This "why not?" test is based on the premise that futures markets ordinarily provide economic benefits unless there is a flaw in either the contract or the market. An advisory committee to the CFTC explained the rationale:

> The "why not?" test used by the Commission is founded on the perception that futures markets ordinarily provide economic benefits through hedging and price discovery. Futures prices guide production, storage, and consumption decisions which help the economy function more smoothly. The futures markets do not normally create risk, but rather permit already existing risk to be shifted to those most willing and best able to carry them. Thus, a futures contract which is likely to be actively traded on an organized futures market can be expected to provide economic benefits -- unless it has a flaw. Thus, the "why not?" test is the correct approach (CFTC, 1976).

If the premise that financial futures are valuable for forecasting and hedging is to serve as the basis for CFTC policy toward these markets, it should be supported by a solid body of empirical evidence. Therefore, a study of the hedging and price discovery performance of the CD futures market should be especially relevant for policy makers.

Since July 1981, futures contracts specifying a negotiable certificate of deposit (CD) as the deliverable instrument have been traded at the International Monetary Market of the Chicago Mercantile Exchange. Before this time, commercial banks often resorted to using other futures contracts - usually Treasury bills - in order to hedge against adverse movements in the interest cost of issuing CD liabilities. In the first part of this study, the hedging performance of the CD futures market will be evaluated. The effectiveness of hedging short-term CDs with CD futures will be compared to hedges constructed with Treasury-bill futures.

The second part of this study will be devoted to evaluating the price-discovery performance of the CD futures market. To do this, a direct test of the efficient markets hypothesis will be employed.

Hedging Performance

The increase in the use of interest-sensitive liabilities by commercial banks during the 1970s has forced bank managers to be more conscious of the interest-rate risk inherent in mismatched maturities of assets and liabilities. If interest rates remain variable in coming years, banks will be forced to develop new techniques to manage interest-rate risk in order to satisfy customer needs and maintain profitability. Increased use of the financial futures markets for hedging purposes has been suggested as one such set of techniques.

One maturity mismatch faced by banks is between term loans and short-term CDs (CDs with maturities of 30, 60, 90 and 120 days). For example, a bank may finance a fixed-rate term loan by issuing and rolling over a series of CDs. The bank manager does not know how much it will cost to roll over a short-term CD three, six, or nine months into the future. Interest rates could rise to a level higher than those expected by bankers. It is possible that interest rates could rise to such an extent that the cost of servicing the CDs would exceed the revenue gained from the fixed-rate loan.

The futures market allows those who anticipate a position in the CD market to avoid the consequences of unexpected movements in CD rates. A bank could sell CD futures in the contract month nearest the month the bank needs the funds and then offset the futures position when the CDs are issued.[2] If the hedge is effective, adverse unanticipated interest rate movements in the spot CD market will be offset by gains in the futures market. Conventional wisdom suggests, however, that hedges will never be entirely effective, so that interest rate risk cannot be eliminated.[3]

Before July 1981, CD futures were not traded so that banks often used other futures contracts - usually Treasury-bill futures contracts - as hedging instruments. A study by Hicks (1980) suggested that the effectiveness of hedging anticipated CD positions could be improved with the development of a CD futures contract. Market studies by the Chicago Mercantile Exchange, the Chicago Board of Trade and the New York Futures Exchange showed that banks would use such a contract if it existed. As a result of these studies, the CFTC granted approval of CD futures contracts on these exchanges in the Spring of 1981. The expectation of all parties was that the CD futures contract would provide a vehicle for hedging short-term CDs that was more effective than Treasury-bill futures.

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[2]The strategy is limited in that CD futures contracts extend only 18 months into the future.

[3]The type of hedging strategy described here is known as a "microhedge." This means the bank hedges specific interest-sensitivity mismatches. Alternatively, the bank could use a macrohedging strategy. With a macrohedge, the bank hedges the net interest-sensitivity mismatches calculated from the bank's consolidated balance sheet (See Short, 1982).

Since July 1981, CD futures have been traded on these three exchanges with almost all volume being at the International Monetary Market (IMM) of the Chicago Mercantile Exchange. At present, CD futures are traded in six different contract months with the underlying instrument being a 90-day CD from one of several large "no-name" banks.

Although there are several studies on the hedging performance of financial futures markets, none has examined the CD futures market specifically. Previous hedging studies were conducted before CD futures markets were established. Nearly three years have passed since CD futures began trading. The volume has been strong, especially on the nearby contract, since the start of trading. This is a large enough data base from which to begin assessing this market's hedging performance.

Price Discovery Performance

The second economic function of a futures market is price discovery. If the futures price is formed by fully reflecting all available and relevant information, the market is said to be efficient. Efficient markets ensure that the market is performing its price discovery function.

The macroeconomic importance of market efficiency is derived from the role of prices as aggregators of information. When markets are efficient (in the sense of reflecting information), economic agents who make decisions on the basis of observed prices will be allocating resources more efficiently.

Both parts of the study will be of particular interest to the banking industry and its regulators. Bankers will be interested in knowing how CD futures and Treasury-bill futures compare as hedges for short-term CDs. They will benefit from knowing whether or not hedging performance has been improved with the introduction of CD futures.

Bankers will also be interested in knowing whether CD futures provide unbiased estimates of future spot CD rates. If the CD futures market is efficient, all available information should be incorporated in the futures rate. This rate will then represent the market's best guess of future spot rates. This information can help determine how much to charge a customer for a fixed-rate loan. The more efficient the futures market, the better it will be as a hedging instrument. During the life of the hedge, the futures price should change to reflect new information just as the hedgers expectations of future spot rates change in response to new information. If the futures market was not efficient, it would not do a good job of offsetting unanticipated movements in interest rates.

CHAPTER II. INSTITUTIONAL CONSIDERATIONS

To understand methods of evaluating the CD futures market's hedging and price discovery performance, it is necessary to be familiar with some institutional details of the markets involved. Therefore, a description of the spot, futures and forward markets for CDs will be presented as will a description of the T-bill futures market.

The Spot CD Market

The negotiable bank certificate of deposit, or CD, has served banks as a major source of funds since the instrument was introduced by Citibank in 1961. CDs form an important segment of short-term portfolios of corporations, state and local governments, foreign central banks, and money market mutual funds. An active secondary market exists meaning that CDs can provide liquidity for investors - a characteristic that ordinary time deposits do not possess. The CD is important for domestic banks because it allows them to tap the national market for funds.

Large negotiable CDs are issued in denominations ranging from $100,000 to $10,000,000 and may be traded in a secondary market. Almost all CDs issued in the domestic market have a maturity of less than one year. Interest is paid at maturity. Market quotes are based on a bond equivalent yield calculation.

The original investor agrees to deposit funds with the bank for a specified period - generally one, two, three, or six months. In return, the investor receives a certificate of deposit. At the end of the specified period, the holder of the CD receives from the bank the amount of the original deposit plus interest. The original depositor need not hold the CD until maturity, but may sell it in a secondary market where the quality of the issuing bank, yield, and the time to maturity will determine the price received. The CD is treated as a money-market instrument by the investor because the deposit may be bought and sold in a secondary market, unlike ordinary deposits. A CD is treated as a deposit liability by the issuing bank. The bank must hold reserves and pay FDIC insurance on the amount deposited.

The primary market for CDs consists of the issuing banks, the dealers who make the market in CDs, and investors. The issuing banks are segregated by risk into a number of tiers. Top-tier CDs are those of the largest domestic banks. These CDs are sometimes called "no-name" CDs because the quality within this tier is homogeneously high, and the investor is, therefore, indifferent as to which bank issued the instrument. This homogeneity makes top-tier CDs a suitable delivery vehicle for a CD futures contract. The top tier consists of about 10 major banks. The second tier contains another 10 or 20 banks that may have to pay 10 to 20 basis points more than the top tier. The third tier includes regional and resident foreign banks whose CDs trade at a rate 20 to 50 basis points higher than first-tier banks (Meek, 1983).

About 30 dealers are active in making a secondary market in CDs. Dealers normally maintain inventories of the first- and second-tier CDs for their customers.

Most volume in the CD market is in the one-to-three-month range. There is a market for six-month paper, but it is thin, and the market for one-year paper is still thinner.

Bank CDs, unlike government securities, possess a degree of credit risk so that the bank pays a default premium on the CDs it issues. Moreover, it has been observed that during periods of rising interest rates, there is a flight to quality so that banks must pay an even higher premium in order to attract funds. Compared to the rates on Treasury bills, the rates on CDs will rise faster during periods of rising rates and fall faster during periods of falling rates. This is represented in Figure 2.1. This credit risk is an important difference between private debt and public debt.

The CD Futures Market

Futures contracts are standardized forward contracts that are traded on organized futures exchanges. Futures contracts are legally binding agreements which obligate the seller of the contract to deliver the commodity specified in the contract to the buyer at some future date at some fixed price. With a futures contract, nearly all physical aspects of the contract are standardized and homogeneous. Unlike the cash market, where maturity, issuer, price, quantity and other information must be explicitly stated, buying or selling a futures contract is limited to one variable -- price. Thus, futures contracts allow ease of quotation and trading.

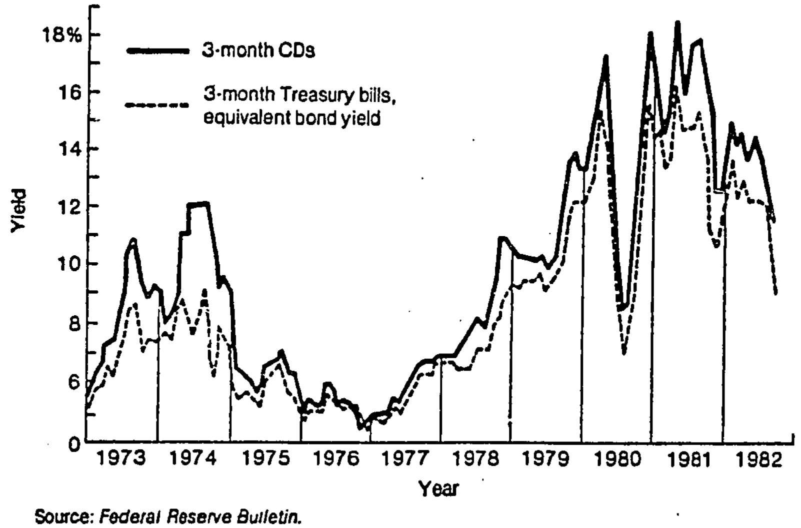

Figure 2.1. CD rates and T-bill rates compared

Two positions can be taken in a futures market. If a futures contract is purchased, the investor is said to have a "long" position. By purchasing a futures contract, the investor is entitled to accept delivery of the standardized commodity specified by the contract at some future date at a price determined when the long position is established. A futures contract may also be sold in which case the investor is said to have a "short" position. By selling a futures contract, the investor is obligated to deliver the specified commodity when the contract matures at a price determined when the short position is established.

Specifications of the futures contract are identical for both long and short positions.

Specifications of the 90-day CD futures contract

The 90-day CD futures contract is similar to other futures contracts in that the terms are standardized with respect to the quantity and quality of the deliverable commodity and the location and time of contract maturity. Specifically, the CD futures contract calls for the delivery or receipt of a 90-day CD from a top-tier bank with a maturity value of $1,000,000. A summary of contract specifications for CD and T-bill futures are presented in the Appendix A.

In the spring of 1981, the Commodities Futures Trading Commission gave permission to the Chicago Board of Trade, the New York Futures Exchange, and the International Monetary Market to trade a domestic CD futures contract. The IMM contract turned out to be the one that succeeded among the three contracts approved. The IMM had the advantage of being the exchange where the T-bill contract was traded. The spread trade between CD futures and T-bill futures was popular from the start of trading and a key source of liquidity in the IMM CD futures contract.

Contracts currently extend out 18 months with delivery months in March, June, September and December. At any give time, then, there are normally six contracts trading. For example, in October, 1983, the following contracts were trading: December, 1983; March, 1984; June, 1984; September, 1984; December, 1984, and March, 1985. When the December, 1983 contract expires, a new contract for June, 1985 will begin trading.

The CD futures contract calls for the delivery of a 90-day CD between the 15th and the last day of the delivery month. Delivery is made to a Chicago bank that is both registered with the IMM and a member of the Federal Reserve System. Payment for the securities delivered is conducted through wire transfer of Federal funds.

<u>The quotation of contract prices</u>

CD futures are quoted in terms of an index. This index is the difference between 100 and the annualized percentage discount yield (as opposed to the bond equivalent yield used in the spot CD market) of the underlying security. For example, if the annualized discount rate on a 90-day CD is 8.5 percent, then the index price would be 91.50.

On a hundred point index, each hundredth of a point is one basis point. This being so, the one hundred point index can be expressed as 10,000 basis points. The basic CD futures contract calls for delivery of a 90-day CD with a maturity value of $1,000,000. If the underlying CD had a maturity of one year, each basis point would be worth $100 ($1 million divided by 10,000 basis points), but the contract specifies delivery of 90-day CDs. Each basis point is worth, therefore, $25. Given this, gains and losses in the market can be calculated. If the index price of the futures contract declines eight basis points from 91.54 to 91.46 (i.e., the discount rate has risen from 8.46 to 8.54), then the value of the contract has fallen $200.

This method of quoting CD futures contracts preserves the traditional futures market relationship in which the long (short) position profits when the contract's price rises (falls). Because of the inverse relationship between yields and prices on CD contracts, the traditional method of quoting CDs on a yield basis would not conform with the traditional futures market relationship. The actual price paid is computed by using the annual rate of discount expressed in decimals:

$$\text{net invoicing price} = \frac{\text{maturity value}}{\left[1 + (\text{CD yield}) \ \frac{\text{days to maturity}}{360}\right]}$$

where the maturity value on discount CDs means principal value. Maturity value on add-on CDs means principal plus interest payable at maturity. CD yield = (100.00 - Index Price) x .01.

Costs of futures trading

The costs of futures trading may be divided into two categories: commissions and margins. Commissions on futures contracts are assessed on a "round turn" basis, i.e., the commission covers both entry and exit from the futures market. All positions, long or short, must pay commissions. A round-turn commission on one CD futures contract is negotiable but is typically close to 50 dollars.

In addition to commission charges, margin money must be posted. The initial margin serves as a security bond to ensure contract performance. The initial margin is deposited by both parties to the transaction when the position is established. Margin requirements in futures trading differs from stock market margin requirements. In the stock market, the margin is a partial payment to purchase securities. An actual transfer of property ownership occurs. Margin in the futures market involves no transfer of property. Currently, the initial margin for CD futures is $2,000 per contract.

Futures market margin requirements have a close relationship to daily price limits. Margin is generally set at a level to cover the possible financial loss that can occur during a single trading session. Currently, the daily limit move for CD futures is 80 basis points; therefore, the margin requirements is $2,000 ($25 x 80 basis points).

A maintenance margin is usually set at 75 percent of the initial margin. For the CD futures market the minimum maintenance margin would be $1,500. The purpose of specifying a maintenance margin is to ensure performance on the contract by protecting the contract holder against large accumulated losses. If the investor is long (short) in futures and the price of the contract falls (rises) to such an extent that losses exceed $500 per contract, i.e., the margin balance falls below $1,500, the investor will be advised to restore the margin account back to the original level of $2,000. These "margin calls" must be made in cash to the brokerage firm before the commencement of trading the next business day.

The daily settlement procedure of crediting or debiting the margin balance according to the daily price movements of the futures contract is called "marking-to-market." For as long as the futures position is outstanding, the contract will be marked-to-market at the end of each business day.

The size of the market

The closing IMM index value and the total amount of open interest in all the CD futures contracts traded on October 25, 1983 are shown below:

Table 2.1. Open interest on CD futures contracts (October 25, 1983)

Contract	IMM Index (Settlement)	Open Interest (number of contracts)
Dec. 83	90.40	11,956
March 84	89.97	6,807
June 84	89.65	3,409
Sept. 84	89.41	1,076
Dec. 84	89.18	238
March 85	88.98	6

Open interest is the total number of basic contracts which have come into existence and which have not yet been offset by an opposite futures transaction. Each basic contract has both a buyer and a seller, but for the purpose of calculating open interest, only one side of the contract is counted. Open interest is used as an indicator of depth and liquidity in the market.

From Table 2.1, it can be seen that most of the open interest is in the contracts closest to maturity. For the December 1983 and March 1984 contracts, the average actual price of each CD contract was approximately $975,500. This price when multiplied by the open interest in these two contracts yields $18.3 billion. For the other four contracts being traded on this date, the total dollar value of open interest was approximately $4.6 billion.

Figure 2.2 shows the growth of the CD futures market since its beginning in July 1981. As can be seen from the graph, volume has been strong since the beginning of trading. The CD futures market is growing and today is moderately sized. It is not a thin market, but it is small compared to the T-bill futures market. Table 2.2 shows open interest on T-bill futures contracts traded on the IMM October 25, 1983. Comparing this table to Table 2.1 illustrates the relative sizes of the CD and T-bill futures markets.

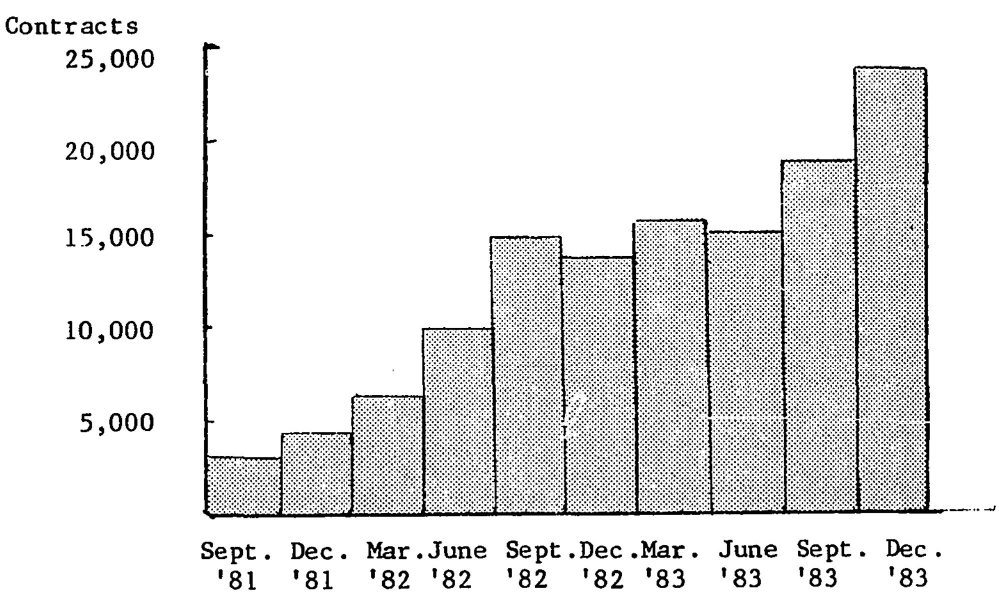

Figure 2.2. Average daily open interest on all CD futures contracts traded at I.M.M. (number of contracts)

Table 2.2. Open interest on T-bill futures contracts (October 25, 2983)

Contract	IMM Index (Settlement)	Open Interest (number of contracts)
Dec. 83	91.07	31,169
March 84	90.68	14,264
June 84	90.41	3,957
Sept. 84	90.18	1,431
Dec. 84	89.97	352
March 85	89.97	109
June 85	89.56	117
Sept. 85	89.40	12

The Treasury-Bill Futures Market

The CD and T-bill futures markets are similar in many respects. Both contracts specify a 90-day instrument worth $1 million at maturity. Both are quoted on a comparable index. Both are traded on the same exchange and share some common delivery months. However, there are some differences in the specifications of the two contracts.

First, the underlying security of the T-bill futures market is a 90-day T-bill. Each issue of Treasury bills is completely homogeneous. There is no variation in the quality of the credit behind the bills. Treasury bills are the most standardized and homogeneous of all money market instruments. They also possess a high degree of liquidity.

Second, the daily limit price move for T-bills futures is 60 basis points as opposed to the 80 basis points for CD futures. This means that the minimum initial margin will be $1,500 and maintenance margin will be $1,200.

Third, when a Treasury-bill futures contract matures, delivery is made on the business day following the last day of trading. This is usually the third Thursday of the delivery month. This one-day delivery period differs from the two-week "delivery window" in the CD futures market.

Finally, each contract is traded for a period of two years with eight contracts trading at any given time. This differs from the 18-month trading period for CDs. In October, 1983, the following T-bill futures contracts would be trading: December, 1983; March, 1984; June, 1984; September, 1984; December, 1984; March, 1985; June, 1985; and September, 1985.

Forward Versus Futures Markets

In a forward transaction, a seller agrees to deliver goods to a buyer at some future date at some agreed-upon price. For example, a bank may agree to sell Federal funds tomorrow at a price specified today.

Forward contracts are not standardized but rather are uniquely specified to suit the individual needs of the agreeing parties. Specified in the terms of the contract are the price, quantity, quality, time and place of delivery, and the terms of payment. Because forward contracts are heterogeneous, they are not traded on an exchange but rather an informal, decentralized market. Margin is not maintained so that forward contracts are not guaranteed in any way except by the faith and credit of the agreeing parties.

A futures contract is really nothing more than a standardized forward contract. Because the futures contract is standardized, they can be traded easily on an organized exchange where only the price of the contract is subject to negotiation. Because margin is required on futures contract and because of the mark-to-market procedure, the performance on the contract is guaranteed. There is no risk of default as there is with forward contracts. Because of this, the futures market has more depth and liquidity than the forward market.

Forward contracts are usually made with the intention to accept delivery on the contract. It is generally not possible to offset an open position in the forward market before maturity because forward contracts are non-negotiable agreements. To liquidate an open position in the futures market simply involves taking an offsetting position sometime before the contract reaches maturity and, in fact, most positions taken in the futures markets are offset before maturity of the contract.

CHAPTER III. METHODS OF EVALUATING HEDGING AND PRICE DISCOVERY PERFORMANCE

In this chapter, methods of evaluating the hedging and price discovery performance of the CD futures market will be developed. In the first section, previous hedging studies will be discussed. The shortcomings of these studies will be identified and improvements will be suggested for evaluating the anticipatory hedging performance of the CD futures market. In the second section, a direct test of the efficient markets hypothesis will be developed for evaluating the CD futures market's price discovery performance.

Evaluating Hedging Performance

When reading the literature on hedging, one must be careful to distinguish between two distinct types of hedges: One involves an existing position in the cash market; the other is where a cash position has not been taken but is expected to be taken in the future. The former situation may be called a cash hedge, while the latter is known as an anticipatory hedge. The distinction is important because, although hedging in commodity markets is conducted primarily to protect an actual position in the cash market, hedging in the financial markets is often most useful for anticipatory hedging; i.e., hedging the interest rate at which one will borrow or lend (Franckle and Senchack, 1982).

Hedging performance should be evaluated in comparison to the objective of the hedger. With a cash hedge, the objective of the hedger is to avoid the consequences of adverse changes in spot prices. In commodity markets, as well as some financial markets, the performance of this type of hedge can be evaluated by comparing changes in spot prices with changes in futures prices; i.e., the hedge can be evaluated by looking at the basis.[1] If spot and futures prices move together, i.e., the basis is stable, then the hedge is said to be effective because losses in the spot market will be offset by gains in the futures market.

With financial instruments, the objective of the hedger is seldom met by constructing cash hedges. The main reason for this is that in order to hedge an existing cash position, it is necessary to have a storable commodity. A financial instrument is not storable because its identity changes over time. This problem becomes more apparent the shorter the maturity of the instrument. For example, one day after purchase, a 90-day T-bill becomes an 89-day T-bill, an 88-day T-bill the next day, etc. One consequence of this problem is that over time the cash market instrument becomes less like the instrument in the futures contract. As a result, movements in the market value of the cash instrument become less correlated with movements of futures contract prices.

There have been several studies of the hedging performance of various futures markets (see Cicchetti, Dale, and Vignola, 1981; Hegde, 1981; Dale, 1981; Ederington, 1979; Hicks, 1980; Stein, 1961; Telser, 1955; Peck, 1975; Johnson, 1960; Ward and Fletcher, 1971; Franckle and McCabe, 1979; Senchack, 1980; Working, 1953a, 1953b, 1970; and Parkinson, 1981).

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[1]The difference between the futures price and the spot price is the basis. If futures prices and spot prices move together, the basis will be stable. If they do not move together, the basis is said to be variable. When futures and spot prices do not move together over the life of the hedge, the hedger is said to be exposed to "basis risk".

However, none is concerned specifically with the hedging performance of the CD futures market.

Ederington (1979) attempted to evaluate the hedging performance of the T-bill and GNMA futures markets by applying a cash-hedging model developed by Johnson (1960). Hicks (1980) also used this framework to evaluate the performance of the T-bill futures market for hedging anticipated spot positions in the T-bill and CD markets.

In Ederington and Hicks' version of the model described above, it is assumed that the hedger anticipates taking a position in a spot market instrument. In this model, E(U) represents the expected change in value of a spot position between the time the position is anticipated and the time it is actually taken.

$$(3\text{-}1)\quad E(U) = X_t^s\, E(S_t - S_{t-k})$$

$$(3\text{-}2)\quad Var(U) = \left(X_t^s\right)^2\, Var(S_t - S_{t-k})$$

where X_t^s is the maturity value of the financial instrument X that will be a spot market liability at time t (when the position is taken), S_t is the spot index price at time t, and S_{t-k} is the spot index price at time t-k (when the position is anticipated). Var(U) is the variance in the change of spot market values.

The expected change in value associated with hedging an anticipated spot position with a futures position can be represented by E(H):

$$(3\text{-}3)\quad E(H) = X_t^s E(S_t - S_{t-k}) + X_{t-k}^f E\left(F_t^{t+T} - F_{t-k}^{t+T}\right) - K\left(X_{t-k}^f\right)$$

$$(3\text{-}4)\quad Var(H) = \left(X_t^s\right)^2 Var\,(S_t - S_{t-k}) + \left(X_{t-k}^f\right)^2 Var\,\left(F_t^{t+T} - F_{t-k}^{t+T}\right) + 2X_t^s X_{t-k}^f\, Cov\,\left(S_t - S_{t-k},\, F_t^{t+T} - F_{t-k}^{t+T}\right)$$

where $K(X^f_{t-k})$ are brokerage and other costs of engaging in futures transactions including the cost of providing and maintaining margin. Futures market holdings, X^f_{t-k}, are measured in terms of maturity value of the underlying security. F^{t+T}_t and F^{t+T}_{t-k} represent the futures price on the t+T contract observed in period t and t-k respectively.

The proportion of the anticipated spot market position that is hedged is defined to be β, where $\beta = -X^f_{t-k}/X^s_t$. Equations (3-3) and (3-4) can then be rewritten as:

$$(3\text{-}3') \quad E(H) = X^s_t \{(1-\beta)E(S_t - S_{t-k}) + \beta E(S_t - S_{t-k}) - \beta E(F^{t+T}_t - F^{t+T}_{t-k})\} - K(X^f_{t-k})$$

$$(3\text{-}4') \quad Var(H) = (X^s_t)^2[Var(S_t - S_{t-k}) + \beta^2 \, Var(F^{t+T}_t - F^{t+T}_{t-k})] - 2\beta \, Cov(S_t - S_{t-k}, F^{t+T}_t - F^{t+T}_{t-k})$$

The proportion of the anticipated position hedged, β, will affect the expected change and variance of changes of the value of the hedged position. Holding X^s_t constant, the effect of varying β on the expected change in value of the position can be found by differentiating equation (3-3') with respect to β:

$$(3\text{-}5) \quad \frac{\partial E(H)}{\partial \beta} = -X^s_t[E(F^{t+T}_t - S_t) - E(F^{t+T}_{t-k} - S_{t-k}) + E(S_t - S_{t-k})] - \frac{\partial K(X^f_{t-k})}{\partial \beta}$$

The effect of varying β on the variance of changes in value of the position can be found by differentiating equation (3-4') with respect to β:

$$(3\text{-}6) \quad \frac{\partial Var(H)}{\partial \beta} = (X^s_t)^2[2\beta Var(F^{t+T}_t - F^{t+T}_{t-k}) - 2 \, Cov(S_t - S_{t-k}, F^{t+T}_t - F^{t+T}_{t-k})]$$

Setting $\partial Var(H)/\partial\beta = 0$ and solving for the risk-minimizing β:

$$(3\text{-}7)\quad \beta^* = Cov\left(S_t - S_{t-k}, F_t^{t+T} - F_{t-k}^{t+T}\right)/Var\left(F_t^{t+T} - F_{t-k}^{t+T}\right)$$

The portfolio model provides a measure of hedging effectiveness. Although the risk reduction achieved by any one hedger depends on the chosen β, the futures markets' potential for risk reduction can be measured by comparing the risk on an unhedged position with the minimum risk that can be obtained by hedging with futures contracts. The measure of hedging effectiveness is defined to be the percent reduction in the variance achieved by having an optimally hedged position as opposed to having an unhedged position:

$$(3\text{-}8)\quad e = 1 - [Var(H^*)/Var(U)]$$

Substituting equation (3-7) into equation (3-4') yields:

$$(3\text{-}9)\quad \left(X_t^s\right)^2 \left\{ Var(S_t - S_{t-k}) - \frac{\left[Cov\left(S_t - S_{t-k}, F_t^{t+T} - F_{t-k}^{t+T}\right)\right]^2}{Var\left(F_t^{t+T} - F_{t-k}^{t+T}\right)} \right\}$$

Combining equation (3-9) with equation (3-8) yields:

$$(3\text{-}10)\quad e = \frac{\left[Cov\left(S_t - S_{t-k}, F_t^{t+T} - F_{t-k}^{t+T}\right)\right]^2}{Var(S_t - S_{t-k})Var(F_t^{t+T} - F_{t-k}^{t+T})}$$

$$(3\text{-}11)\quad e = \rho^2$$

where ρ^2 is the population coefficient of determination between the change in the spot price and the change in the futures price.

The parameter e can be estimated by using the sample coefficient of determination, R^2, for hedges of arbitrary length. Using the sample variance and covariance for the observed period, β^* can also be estimated. For example, Ederington and Hicks would estimate the effectiveness of a k-day hedge using the following equation:

$$(3\text{-}12) \quad (S_t - S_{t-k}) = a + b\left(F_t^{t+T} - F_{t-k}^{t+T}\right) + \mu$$

However, the model has serious shortcomings when applied to either cash or anticipatory hedges of financial instruments. With cash hedges, Johnson's model is applicable only when storable commodities are being hedged. Ederington used a non-storable commodity -- T-bills -- and neglected to account for the problems caused by the violation of this condition. With anticipatory hedges, Johnson's model is not consistent with the objective of the hedger unless the yield curve is flat, i.e., only when interest rates are not expected to change. With anticipatory hedges, one is not hedging against adverse movements in the spot price per se, but rather one is hedging against movements in the spot price relative to the expected spot price. Ederington and Hicks did not adequately account for the hedger's expectations of future spot prices.

To illustrate the shortcomings of this framework for evaluating anticipatory hedges, consider the following example. Suppose that a commercial bank plans to make a 6-month, fixed-rate loan for $1,000,000. Suppose also that this loan is financed by first issuing a 90-day CD for $1,000,000 when the loan is made (in February) and then another when the first CD matures (in May). The bank would like to lock in a rate in February for the CD that is issued in May. The bank does not need to hedge the CD issued in February, since this rate is known with certainty at the time the loan is made. The bank could try to hedge the May CD rate by selling short in February $1 million of June CD futures and then offsetting the futures position in May.

Assume that the spot 90-day CD rate is 10 percent in February. Suppose, also, that based on all available information, the bank expects the spot rate to rise to 11 percent in May. The price of the June CD contract in February is quoted at 88.00.

Now suppose that spot CD rates actually rise to 12 percent in May -- 1 percent more than what was expected in February. Assume the CD futures are quoted at 87.00 when the hedge is lifted in May. All rates are annualized discount yields.

The results of the hypothetical hedge can be represented by the following table:

	Spot	Futures
February	Spot CD = 10% (90.00) expected spot CD in May = 11% (89.00)	sell $1 million June CD futures at 88.00
May	issue $1 million in spot CDs at 12% (88.00)	Buy $1 million June CD futures at 87.00
	surprise = -100 basis points = -$2,500.	100 basis points $2,500 gain

In this example the surprise in the spot market (1 percent, 100 basis points, or $2,500) is perfectly offset by the hedge. With a good hedging vehicle, the bank can treat its expectation of the May spot CD rate as given and price the fixed-rate loan accordingly. By hedging, the range of future outcomes should be reduced so that there is less uncertainty about pricing a fixed-rate loan today.

What is being hedged is not the change in spot prices as the term $(S_t - S_{t-k})$ of equation (3-12) implies. Instead, with an anticipatory hedge, the objective of the hedger is to avoid the consequences of unwelcome surprises. The surprise, or rather the difference between future spot prices and expected future spot prices, can be represented by the following term:

$$\text{Surprise} = S_t - E(S_t | \phi_{t-k})$$

where S_t is the spot index price in period t, and $E(S_t | \phi_{t-k})$ is the expectation of the spot price for period t conditioned on information set, ϕ_{t-k}, available at time t-k.

The method used by Ederington and Hicks implies that the expected future spot price equals the spot price at the beginning of the hedge. However, for many hedges, the assumption that $S_{t-k} = E(S_t | \phi_{t-k})$ is not reasonable. Applying to anticipatory hedging a model designed for cash hedging is generally a mistake. The consequences of this error may not be too severe, however, since Ederington and Hicks look at hedges constructed for short periods of time. In these cases, it may not be unreasonable to suppose that the spot price is a good proxy for the expected future spot price.

In general, the spot price will not be the best estimator of the future spot price, and because of this, a stable basis can no longer be regarded as an appropriate criterion for determining the effectiveness of a hedge. Consider the case where the yield curve is upward sloping, i.e., the market expects interest rates to rise. In such a case, one would expect the basis to narrow over the life of the hedge. Assume, for analytical purposes, that the hedge is lifted during the delivery month. If the futures instrument and the spot instrument are the same, then the futures price should converge toward the spot price at delivery. With an upward-sloping yield curve, the basis at the beginning of the hedge will be wider than the basis in the delivery month when the hedge is lifted.

The yield curve is an important part of the basis especially when short-term instruments, such as CDs and T-bills, are being hedged. For hedges constructed with longer-term instruments, such as GNMA certificates and T-bonds, this consideration is not as important because the flat range of the yield curve then becomes relevant.

In conclusion, then, the method used by Ederington and Hicks to evaluate the performance of anticipatory hedges is reasonable if either the hedging length is short or a long-term instrument is being hedged.

A Method for Evaluating the Effectiveness of Anticipatory Hedges

A portfolio model of the general type developed by Johnson can be used to evaluate the effectiveness of anticipatory hedges. However, several modifications must be made so that the hedger's expectations are adequately considered.

Assume, as before, that the hedger anticipates taking a position in one spot market instrument. Letting E(U) represent the expected value of a surprise conditioned on information available when the position is anticipated.

(3-13) $E(U|\phi_{t-k}) = X_t^s E(\text{surprise}|\phi_{t-k})$

(3-14) $Var(U|\phi_{t-k}) = (X_t^s)^2 Var(\text{surprise}|\phi_{t-k})$

The expected value of a spot market surprise offset to some degree with a futures position can be represented by E(H):

$$(3\text{-}15)\quad E(H|\phi_{t-k}) = X_t^s E(\text{surprise}|\phi_{t-k}) + (X_{t-k}^f)E[(F_t^{t+T} - F_{t-k}^{t+T})|\phi_{t-k}] - K(X_{t-k}^f)$$

$$(3\text{-}16)\quad Var(H|\phi_{t-k}) = (X_t^s)^2 Var(\text{surprise}|\phi_{t-k}) + (X_{t-k}^f)^2 Var[(F_t^{t+T} - F_{t-k}^{t+T})|\phi_{t-k}] + 2X_t^s X_{t-k}^f \text{ Cov } [(\text{surprise}, F_t^{t+T} - F_{t-k}^{t+T})|\phi_{t-k}]$$

The "expected surprise" in equations (3-13) and (3-15) is, of course, equal to zero. Also, the term $E[(F_t^{t+T} - F_{t-k}^{t+T})|\phi_{t-k}]$ can be shown to equal zero if F_t^{t+T} and F_{t-k}^{t+T} both represent the market's rational expectation of spot prices in period t+T. If this condition holds, then:

$$(3\text{-}17)\quad F_t^{t+T} = E(S_{t+T}|\phi_t)$$

and

$$(3\text{-}18)\quad F_t^{t+T} = E(S_{t+T}|\phi_{t-k})$$

This means that the term $E[(F_t^{t+T} - F_{t-k}^{t+T})|\phi_{t-k}]$ can be rewritten as:

$$(3\text{-}19)\quad E\{[E(S_{t+T}|\phi_t) - E(S_{t+T}|\phi_{t-k})]|\phi_{t-k}\}$$

which, using the law of iterated projections as defined by Sargent (1979), can be rewritten as:

$$(3\text{-}20)\quad E[(S_{t+T} - S_{t+T})|\phi_{t-k}] = 0$$

This result justifies the conclusion that if information is used rationally and if costs associated with futures trading are small enough to be considered zero, then the expected return on both a hedged and an unhedged portfolio will be zero. What becomes relevant in this discussion is the conditional variances and covariances of surprises and changes in futures prices.

Define, as before, the hedge ratio β to be:

$$\beta = -\frac{X^f_{t-k}}{X^s_t}$$

Substituting β into equation (3-16) yields:

$$\text{(3-21)} \quad Var(H|\phi_{t-k}) = (X^s_t)^2 Var(surprise|\phi_{t-k}) + \beta^2 Var[(F^{t+T}_t - F^{t+T}_{t-k})|\phi_{t-k}] - 2\beta Cov[(surprise, F^{t+T}_t - F^{t+T}_{t-k})|\phi_{t-k}]$$

As in Johnson's model, the measure in hedging effectiveness is defined to be the percent reduction in the variance associated with having an optimally hedged position as opposed to having an unhedged position:

$$\text{(3-22)} \quad e = 1 - [Var(H^*|\phi_{t-k})/Var(U|\phi_{t-k})]$$

In Ederington and Hicks' version of Johnson's model, the hedger chose a futures position that minimized the variance of changes in value of a hedged position. Risk minimization is not ordinarily consistent with expected utility maximization as hedgers would be concerned with the trade-off between risk and return. However, under the conditions specified in this case, the expected return on a hedged position is zero so that there is no trade-off, meaning that risk minimization will be consistent with utility maximization.

Parkinson (1981) examined the link between hedging and utility maximization and formally defined the conditions where the risk-minimizing hedge ratio is consistent with utility maximization. In the discussion that follows, Parkinson's notation has been changed to conform to the notation used above.

Under the assumption that the conditional distribution of the surprise, $(S_t - E(S_t|\phi_{t-k}))$ and $(F_t^{t+T} - F_{t-k}^{t+T})$ is bivariate normal, the trader's objective function can be expressed as a function of the conditional mean of the portfolio return:

$$(3\text{-}23) \quad \Psi[E(H|\phi_{t-k}), \text{Var}\,(H|\phi_{t-k})]; \quad \psi' > 0,\ \psi'' < 0$$

where

$$(3\text{-}24) \quad E(H|\phi_{t-k}) = X_t^s\, E(\text{surprise}|\phi_{t-k}) + X_{t-k}^f E[(F_t^{t+T} - F_{t-k}^{t+T})|\phi_{t-k}]$$

$$(3\text{-}25) \quad \text{Var}\,(H|\phi_{t-k}) = (X_t^s)^2\ \text{Var}\,(\text{surprise}|\phi_{t-k}) + (X_{t-k}^f)^2\ \text{Var}[(F_t^{t+T} - F_{t-k}^{t+T})|\phi_{t-k}] + 2X_t^s X_{t-k}^f\ \text{Cov}[(\text{surprise}, F_t^{t+T} - F_{t-k}^{t+T})|\phi_{t-k}]$$

Costs of futures trading are assumed to be zero.

The trader is assumed to be risk averse but is also assumed to be concerned with the expected return on the portfolio. In order to ensure the existence of a unique maximum of Ψ with respect to X_{t-k}^f, Ψ is assumed to be quasi-concave.

Given these assumptions, a necessary and sufficient condition for utility maximization is that X_{t-k}^f satisfy:

$$(3\text{-}26) \quad \Psi_1 E[(F_t^{t+T} - F_{t-k}^{t+T})|\phi_{t-k}] + \Psi_2[2X_{t-k}^f\ \text{Var}((F_t^{t+T} - F_{t-k}^{t+T})|\phi_{t-k})] + 2X_t^s\ \text{Cov}[(\text{surprise}, (F_t^{t+T} - F_{t-k}^{t+T}))|\phi_{t-k}] = 0$$

Solving for X_{t-k}^f gives the optimal futures market position:

$$(3\text{-}27)\quad X^f_{t-k} = -\left[\frac{\Psi_1}{2\Psi_2} \quad \frac{E[(F^{t+T}_t - F^{t+T}_{t-k})|\phi_{t-k}]}{Var[(F^{t+T}_t - F^{t+T}_{t-k})|\phi_{t-k}]}\right]$$

$$- X^s_t \frac{Cov[(surprise, (F^{t+T}_t - F^{t+T}_{t-k}))|\phi_{t-k}]}{Var[(F^{t+T}_t - F^{t+T}_{t-k})|\phi_{t-k}]}$$

The first term of (3-27) indicates that a trader is willing to assume additional risk in order to obtain a higher expected return.

However, a good argument can be made that the first term of equation (3-27) will be zero. As shown in equations (3-17) and (3-20), if the terms F^{t+T}_t and F^{t+T}_{t-k} both represent the market's rational expectation of spot prices in period t+T, then the term $E[(F^{t+T}_t - F^{t+T}_{t-k})|\phi_{t-k}] = 0$. Equation (3-27) can then be written as:

$$(3\text{-}28)\quad X^f_{t-k} = -X^s_t \frac{Cov[surprise, (F^{t+T}_t - F^{t+T}_{t-k})|\phi_{t-k}]}{Var[(F^{t+T}_t - F^{t+T}_{t-k})|\phi_{t-k}]}$$

so that:

$$(3\text{-}29)\quad -\frac{X^f_{t-k}}{X^s_t} = \frac{Cov[surprise, (F^{t+T}_t - F^{t+T}_{t-k})|\phi_{t-k}]}{Var[(F^{t+T}_t - F^{t+T}_{t-k})|\phi_{t-k}} = \beta*$$

so that the optimal hedge ratio is the risk-minimizing hedge ratio.

Substituting $\beta*$ from equation (3-29) into equation (3-21) yields:

$$(3\text{-}30)\quad Var(H|\phi_{t-k}) = (X^s_t)^2 \quad Var(surprise|\phi_{t-k})$$

$$- \frac{[Cov[(surprise, F^{t+T}_t - F^{t+T}_{t-k})|\phi_{t-k}]]^2}{Var[(F^{t+T}_t - F^{t+T}_{t-k})|\phi_{t-k}]}$$

Combining equations (3-22) and (3-30) yields:

$$(3\text{-}31)\quad e = 1 - \frac{\mathrm{Var}(\mathrm{surprise}\,|\,\phi_{t-k})}{\mathrm{Var}(\mathrm{surprise}\,|\,\phi_{t-k})} + \frac{\left[\mathrm{Cov}\left[(\mathrm{surprise},\ F_t^{t+T} - F_{t-k}^{t+T})\,|\,\phi_{t-k}\right]\right]^2}{\mathrm{Var}\left[(F_t^{t+T} - F_{t-k}^{t+T})\,|\,\phi_{t-k}\right]\mathrm{Var}(\mathrm{surprise}\,|\,\phi_{t-k})}$$

$$(3\text{-}32)\quad = \frac{\left[\mathrm{Cov}\left[(\mathrm{surprise},\ F_t^{t+T} - F_{t-k}^{t+T})\,|\,\phi_{t-k}\right]\right]^2}{\mathrm{Var}\left[(F_t^{t+T} - F_{t-k}^{t+T})\,|\,\phi_{t-k}\right]\mathrm{Var}(\mathrm{surprise}\,|\,\phi_{t-k})}$$

or

$$(3\text{-}33)\quad e = \rho^2$$

where ρ^2 is the population coefficient of determination between surprises and changes in futures prices.

Both the optimal hedge ratio and the measure of hedging effectiveness can be estimated by regression.

An Operational Model to Evaluate the Hedging Performance of the CD Futures Market.

In order to evaluate the hedging performance of the CD futures market, hedges are constructed for three lengths of time: one week, two weeks, and thirteen weeks. In all cases, the underlying spot market instrument will be a 90-day domestic CD from a large "no-name" bank. The hedges are grouped by their beginning dates according to the number of months prior to the contract month. For example, two-week hedges begun in January for the March futures contract are grouped with two-week hedges begun in April for the June contract. Hedges will be constructed using the CD futures market as the hedging vehicle. These hedges will be compared to hedges constructed with T-bill futures.

The coefficients e and $\beta*$ will be obtained by estimating difference equations constructed for the appropriate hedging lengths. For example, the effectiveness of a thirteen-week hedge will be estimated using the following equation.

$$(3\text{-}34)\quad (S_t - E(S_t|\phi_{t-13}) = a + \beta({}_{cd}F_t^{t+T} - {}_{cd}F_{t-13}^{t+T}) + \mu$$

$$(3\text{-}35)\quad [S_t - E(S_t|\phi_{t-13})] = a + b({}_{tb}F_t^{t+T} - {}_{tb}F_{t-13}^{t+T}) + \mu$$

where ${}_{cd}F$ and ${}_{tb}F$ are used to distinguish between T-bill and CD futures contracts

The expected future spot rate for the one-week and two-week hedges will be approximated by the spot annualized discount rate when the hedge is placed. For the 13-week hedge construction, the expected futures spot rate will be approximated by the implied forward rate. If the pure expectations theory of the term structure of interest rates is correct, then the implied forward rate in the yield curve should reflect the market's expectations of S_t.

The results of the study will then be compared to the results of Hicks (1980) and Parkinson (1981). Hicks found that cross-hedging CDs with T-bill futures is not as effective as traditional T-bill-T-bill futures hedges but that cross hedging does provide some protection against CD rate fluctuations. In particular, Hicks found that the effectiveness of cross hedging CDs with T-bill futures was dramatically lower for hedges begun immediately before Treasury refunding announcements. Parkinson found little difference between the two types of hedge constructions, but his study considered only nearby contracts. Both studies were conducted before the introduction of the CD futures market, so they had to speculate on what effect such a market would have on hedging against CD rate fluctuations. Hicks foresaw a new futures contract specifying CDs as the deliverable instrument as improving prospects for hedging CD interest-rate risk for hedges begun within four months of the contract month. For hedges begun four months or prior to the contract months, Hicks expected to see only modest improvement. Hicks also expected to see improvement in hedging effectiveness during months corresponding with Treasury refunding announcements. Parkinson was skeptical about the benefits derived from the introduction of a CD futures contract. The objective of the present study among other things is to see if, in fact, the CD futures market has improved prospects for hedging CD interest-rate risk.

Evaluating Price Discovery Performance

The second economic function of futures markets is price discovery. If the futures price is formed by fully reflecting all available and relevant information, the market is said to be efficient. Efficient markets ensure that the market is performing its price discovery function.

The efficient markets hypothesis maintains that the expected rate of return to speculation in the futures market -- conditioned on available information -- is zero. Some authors have noted theoretical problems with this proposition since it ignores some intertemporal allocation problems and risk considerations. These theoretical arguments indicate that one should not equate empirical rejection of this notion of efficiency with evidence of market failure. However, this does not remove all interest in tests of the hypothesis. The extent to which the CD futures market can be characterized as an efficient market remains an interesting question that can best be answered through formal econometric analysis.

Several market efficiency studies have been conducted using financial futures markets in recent years (see Burger, Lang, and Rasche, 1977; Capozza and Cornell, 1979; Emery and Scott, 1979; Lang and Rasche, 1978; Poole, 1978; Puglisi, 1978; Rendleman and Carabini, 1979; and Vignola and Dale, 1979, 1980). Most of these studies have examined the possibility of arbitrage opportunities between the T-bill futures and forward markets. These studies are of limited usefulness to the examination of the price discovery performance of the CD futures market, because the CD forward market is not as well developed as the T-bill forward market. As a result, comparisons of futures and relevant CD prices can be made only on a few dates each year. Since CD futures have been traded for only 27 months at the time of this study, an insufficient number of observations are available to perform meaningful tests.

Formally, the efficient markets hypothesis can be expressed as:

(3-36) $F_t^{t+T} = E(S_{t+T} | \phi_t)$

where F_t^{t+T} is the t+T period futures price determined at time t; E is the expectations operator in period t; S_{t+T} is the spot rate in period t+T; and ϕ_t is the information set available at time t. Equation 3-36 expresses the notion that if the market is efficient, the futures price will be driven to the conditional expectation of the future spot price. The efficient markets hypothesis may also be expressed by rewriting equation 3-36 to yield the following form:

(3-37) $F_t^{t+T} - E(S_{t+T} | \phi_t) = 0,$

which is to say that the expected return to speculation is zero.

Fama (1970) argued that sufficient conditions for market efficiency are that (i) there are no transactions costs in trading the contract; (ii) market participants are risk neutral; (iii) market participants form their expectations rationally; and (iv) the acquisition of all information is costless. However, these conditions are not necessary for market efficiency so that rejection of equation 3-36 is not immediately translatable into rejection of the efficiency of the CD futures market.

One alternative to the proposition that market participants are risk neutral is that they are instead risk averse. Risk aversion implies that, in equilibrium, the futures price equals the conditional expectation of the future spot price, plus a risk premium. In this case, futures prices would be biased upward. An unsystematic risk premium must be accounted for in a test of market efficiency.[2] Risk neutrality is not a property required for prices to fully reflect available information.

The assumption that costs of transactions are zero appears to be a valid approximation for the CD futures market. Traders on the floor of the exchange are exchange members and as such pay commissions on each trade. However, these transaction costs are small enough that traders rarely hesitate to take advantage of price moves as small as one basis point. For the purposes of the study, transactions costs may be assumed to be zero.

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[2]If the bias was constant or varied in some predictable way, one could profit from this information. Since futures and spot prices must converge at delivery, other things being equal, one could expect to profit by selling futures and repurchasing them shortly before delivery.

The CD futures market is competitive in the sense that a trader cannot influence the market price by his or her own actions. Although a precise measure of competitiveness is not available, the high volume in the CD futures nearby contracts supports the notion that the market is competitive. Volume is thinner on the more distant contracts, and it is, therefore, conceivable that a large trader could influence these prices. The shortcomings of this assumption must be recalled when interpreting test results.

The information set, ϕ_t, can be divided into three subsets. The first subset consists of past prices or past rates of return. A test of whether the market efficiently utilizes this information is called a test of weak form efficiency. The second subset consists of publicly available information such as government statistics on relevant variables. A test of whether the market efficiently utilizes this kind of information is called a semi-strong form test. The third subset of information consists of information that is priviledged or available only at significant cost. Tests of whether the market efficiently utilizes this kind of information are called strong-form tests.

A testable property of the efficient markets hypothesis is that the forecast revision, $\left(F_t^{t+T} - F_{t-1}^{t+T}\right)$, is uncorrelated with information available at time t-1. A question arises as to which elements of the information set, ϕ_{t-1}, should be used to test this proposition. Although any of the elements of ϕ_{t-1} could be used, the most recent past forecast revisions are likely to generate the most powerful test.

A direct test of the weak-form efficient markets hypothesis can be applied to the CD futures market. A "direct" test uses the actual futures prices as opposed to "indirect" tests which compare futures market forecasts with those of forecasting models or trading systems. Berger (1982) has shown that direct tests reject the null hypothesis of weak-form efficient markets more frequently than indirect tests when the alternative hypothesis is true, i.e., direct tests are more powerful than indirect tests.

The test that will be used involves estimating regressions of forecast revisions on a constant and the two most recent forecast revisions. The regression equation may be expressed as:

$$(3\text{-}38) \quad \left(F_t^{t+T} - F_{t-1}^{t+T}\right) = a + b_1\left(F_{t-1}^{t+T} - F_{t-2}^{t+T}\right) + b_2\left(F_{t-2}^{t+T} - F_{t-3}^{t+T}\right) + \mu_t$$

The operational null hypothesis of weak form efficient markets in a risk-neutral world can be expressed as:

$$H_o: \quad a = b_1 = b_2 = 0$$

To test the joint hypothesis that all coefficients are zero, the F statistic will be appropriate.

CHAPTER IV. EMPIRICAL RESULTS

In this chapter, the main empirical results from the models developed in Chapter III are reported. The first section will be devoted to the reporting of tests of the anticipatory hedging performance of the CD futures market. In the second section, empirical results of market efficiency tests will be discussed.

Empirical Evidence on the Anticipatory Hedging Performance of the CD Futures Market

The CD futures market was established with the expectation that it would provide a vehicle for hedging short-term CDs that was more effective than T-bill futures. The expectation was that new information concerning future spot CD rates would be more fully reflected in the price movements of the CD futures market than in the price movements of the T-bill futures market.

Chapter III presented a method for measuring the effectiveness of anticipatory hedges constructed with CD futures. In this section, this method is applied. Specifically, the effectiveness of hedging anticipated positions in the spot CD market with CD futures will be compared to the effectiveness of hedges constructed with T-bill futures.

The data

The sample period chosen was between July, 1981, the month that CD futures began trading, and September, 1983. Futures data were obtained from the Wall Street Journal and the International Monetary Market of the Chicago Mercantile Exchange. Daily settlement index prices were gathered for the year preceding the maturity date of each contract and averaged into weekly figures. Approximately 52 observations were recorded for each of the 11 CD and T-bill futures contracts examined. Holidays were omitted.

Spot CD prices were obtained from the Board of Governors of the Federal Reserve System. These data consist of secondary market offer rates on 90- and 180-day top tier CDs. These observations were reported in terms of bond equivalent yield.[1] The data were transformed to a discount basis using the following transformation:

$$\text{(4-1)} \quad \text{Annualized spot discount rate} = \frac{360i}{365 + it_{sm}}$$

where i = bond equivalent yield

t_{sm} = time from settlement to maturity (in days)

To make the spot rate conform to the futures index, the discount spot rate was subtracted from 100.

The 90-day CD forward rates were obtained using the pure expectations theory of term structure of interest rates. The implied forward rates were derived using the following formula from Stigum (1981):

$$\text{(4-2)} \quad Y^* = \left(\frac{1 + Y_{180} \frac{180}{360}}{1 + Y_{90} \frac{90}{360}} - 1 \right) \frac{360}{90}$$

where Y_{180} = the annualized add-on yield (in decimals) at which a 180-day (26-week) CD can be bought

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[1] Bond equivalent yield is based on a 365-day year, whereas the discount yield is based on a 360-day year.

Y_{90} = the annualized add-on yield (in decimals) at which a 90-day (13-week) CD can be bought

Y^* = the implied forward annualized discount rate (in decimals) on a 90-day (13-week) CD 90 days from now.

The data were transformed so that they could be used in equation 4-3:

$$(4\text{-}3) \quad \left(S_t - E(S_t | \phi_{t-k})\right) = a + \beta(F_t^{t+T} - F_{t-k}^{t+T}) + \mu$$

where all variables are the same as in Chapter III.

When choosing a proxy for the expected future spot price, there are three candidates. The first is the current spot price. As mentioned previously, this will be a reasonable proxy only when the hedging length is short. For the case of a 13-week hedge, the spot rate would not be a satisfactory proxy.

The second candidate is the futures price. After all, the futures price is formed on expectations of future spot prices. However, there are only four months of the year where the futures price may be used. For other than delivery months, the futures price would be a biased estimator of future spot prices. For example, one would expect the March futures price to provide good insight as to the market's expectation of the future spot price in March. However, the March futures price would not be as satisfactory a proxy for the market's expectation of spot prices in February.

A third alternative is to use the implied forward price. For 13-week hedges on 13-week CDs, the forward price is easy to derive. One disadvantage of using the forward price is that daily observations must be aggregated to weekly observations in order to avoid problems with holidays and weekends. This aggregation removes some volatility from the price series. Also, forward prices can be made to conform with only the 13-week hedging period. This is because the 13-week and 26-week spot rate series for CDs were the only two series available that could be used to derive implied forward prices for 13-week CDs. For example, the price series for 4-week and 13-week CDs would yield an implied rate for a 9-week CD four weeks into the future. This 9-week CD would not conform to the 13-week instrument underlying the futures series. Because of this problem, the implied forward price was used as a proxy for the expected future spot CD price only when 13-week hedges were constructed.

For hedges constructed for 13 weeks, the implied forward price observed in period t-13 is subtracted from the spot price in period t. The resulting variable represents the "surprise" the investor encounters when the cash position is taken 13 weeks in the future. The term $(F_t^{t+T} - F_{t-13}^{t+T})$ represents the change in the futures price (either CD or T-bill futures) over the life of the 13-week hedge.

For hedges constructed for one and two weeks, the spot price in period t-k was used as a proxy for the expected spot price in period t. Because these hedge periods are so short, this approximation should not be unreasonable. In addition, when using these proxies, the results derived can be compared with the results derived by Hicks. As with the 13-week hedges, for the one- and two-week hedges, the "surprise" is represented by subtracting the expected spot price observed in t-k from the spot price in t.

Once the data are transformed into the appropriate hedging lengths, the hedges are grouped by their beginning dates according to the number of months prior to the contract months. For example, two-week hedges begun in January with the March futures contract are grouped with two-week hedges begun in April with the June contract.

To evaluate the hedging performance of the CD futures market and compare it to that of the T-bill futures market, the coefficient of determination, R^2, is used as the test statistic. One problem with this statistic is that it has no known distribution. The most that can be said is that, in general, the higher the R^2 for the various hedge constructions, the more effective the hedge. The null hypothesis is that the difference in hedging effectiveness between CD futures and T-bill futures will be equal to zero:

$$H_0: \; R^2_{CD} - R^2_T = 0$$

$$H_A: \; R^2_{CD} - R^2_T \neq 0$$

where R^2_{CD} and R^2_T are measures of hedging effectiveness for hedges constructed with CD futures and T-bill futures respectively.

In general, it is not a good practice to compare one R^2 statistic with another unless the dependent variables are the same. This consideration requires that care be taken in analyzing the data. Within each hedging length classification, common dependent variables are used so that a direct comparison of hedge constructions may be made. For example, a 13-week CD-CD futures hedge construction (known hereafter as a CD hedge) begun three months prior to the contract month will use the same dependent variable as a 13-week CD-T-bill futures hedge construction (known hereafter as a CD cross hedge) also begun three months prior to the contract month.

Regression analysis

Summary statistics were calculated for various combinations of hedging lengths and starting dates for hedges constructed with CD and T-bill futures. The main objectives are to find values for R^2 and β. However, the economic interpretation of R^2 and β will be valid only as long as the assumptions of the standard linear model are met. If these assumptions are violated, adjustments must be made. In the particular cases studied, the error terms were often serially correlated. Autocorrelation presents two main problems for evaluating hedging effectiveness. First, the R^2 statistic will be biased upward. Second, the standard errors for the βs will be biased downward. This means that tests of significance will be biased even though the estimated values for the risk-minimizing hedge ratios will be left unbiased.

The standard treatment for autocorrelation is to perform a transformation of the original data so that the new error term is independent of errors in other periods. However, this method requires that each equation be transformed differently so that formerly common dependent variables would no longer be common. The R^2 statistics that were comparable could then no longer be compared.

To avoid this problem, a rebuilt R^2 will be used. This permits a generalized least squares (GLS) treatment of the error structure but at the same time preserves common dependent variables. The procedure for deriving the rebuilt R^2 involves two stages. In the first stage, GLS estimates of the intercept and slope coefficients are derived. In the second stage, the original independent variables are used together with the GLS estimates of the coefficients to obtain predicted values of the dependent variables. The rebuilt R^2 statistic is defined as:

$$R^2_{rebuilt} = 1 - \frac{\Sigma(Y_t - \hat{Y}_t^*)^2}{\Sigma(Y_t - \bar{Y})^2}$$

where Y_t represents the dependent variable $\left(S_t - E(S_t|\phi_{t-k})\right)$, from equation 4.3; $\hat{Y}_t^*$ represents the predicted value of the dependent variable using GLS estimate of the model's parameters; and $\bar{Y}$ represents the mean of the dependent variable.

Formally, the corrected predicted value of the dependent variable is defined as

$$\hat{Y}_t^* = a^* + b^* X_t$$

where a* and b* are GLS estimates of the parameters of a and β in equation 4.3. X_t represents the term $(F_t^{t+T} - F_{t-k}^{t+T})$ of equation 4.3.

Using a rebuilt R^2, GLS transformation will not affect the total sum of squares so that models with common dependent variables can still be compared. The error sum of squares will of course change, but it is not necessary nor desirable that this value be preserved. In fact, the reason the data are transformed is to derive an unbiased error sum of squares.

A question arises as to the cause of the observed autocorrelation. This can be explained by looking at the construction of the dependent variable. Consider the following series of observations:

<u>surprise</u>

$$S_t - E(S_t | \phi_{t-k})$$
$$S_{t+1} - E(S_{t+1} | \phi_{t-k+1})$$
$$\vdots$$

An important component of the surprise is the forecast of future spot rates. In this case, the forecast is made k days in advance, i.e., the forecast interval is k days. This construction means that forecasts will share information for k-1 days with both the previous day's forecast and the next day's forecast. Figure 4.1 shows the overlapping forecast intervals for periods t-k and t-k+1.

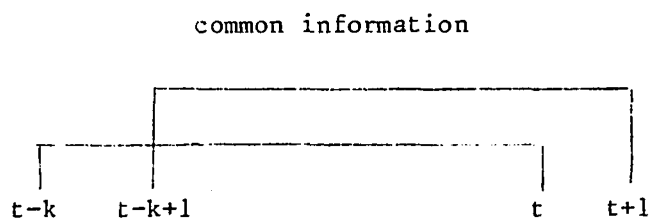

Figure 4.1. Overlapping forecast intervals for forecasts of future spot rates.

Because of these overlapping forecast intervals, one would not expect disturbance terms to be independent. The existence of autocorrelation says nothing about the market's hedging or price discovery performance. It is reflecting only the construction of the dependent variable.

GLS estimates of β are more efficient than OLS estimates. Summaries of both OLS and GLS estimates are presented in Tables 4.1 through 4.4. In addition, differences between the rebuilt R^2 statistics for CD and T-bill hedge constructions are shown in Table 4.5. Mean squared errors for OLS and GLS regression equations are shown in Appendix B.

From these tables, it can be seen that CD futures provide a better vehicle for hedging anticipated cash CD positions than do T-bill futures. In virtually every case, the R^2 statistics for CD hedges are greater than those for CD cross hedges. Moreover, this difference is often quite large.

In general, the shorter the length of the hedge, the less effective the CD hedge and CD cross hedge. This difference is especially pronounced between the short-term (one- or two-week) hedges and the 13-week hedges. This result is consistent with previous hedging studies.

Based on Ederington's study, one would expect hedging effectiveness to decline monotonically the further from the contract month. These results do not indicate such a dependable decline for either CD hedges or CD cross hedges. In fact, effectiveness measures for all hedging lengths suggest that hedges begun in some periods are worse than hedges begun one month earlier or later. Specifically, hedges begun two, five, eight, and eleven months prior to the month the contract matures are relatively less effective than hedges begun one month earlier or later. This is true for both CD hedges and CD cross hedges. The beginning dates for these hedges fall in the months of January, April, July, and October. Before the

Table 4.1. The Effectiveness of Hedging Anticipated Spot CD Positions (one-, two-, and thirteen-week hedges). "e" or R^2 from ordinary least squares estimates of equation 4-3[a]

Number of Months	Treasury-Bill Futures				CD Futures			
Prior to Contract Month	one-week	two-week	13-week (forward)	13-week (spot)	one-week	two-week	13-week (forward)	13-week (spot)
1	.76	.78	-	-	.81	.82	-	-
2	.63	.70	-	-	.70	.74	-	-
3	.55	.51	.88	.87	.71	.68	.99	.90
4	.62	.71	.92	.81	.74	.78	.96	.84
5	.61	.67	.78	.70	.62	.65	.84	.76
6	.59	.54	.93	.81	.75	.73	.93	.79
7	.59	.62	.86	.69	.62	.66	.89	.73
8	.57	.62	.70	.61	.61	.62	.75	.65
9	.57	.52	.86	.71	.76	.75	.87	.72
10	.61	.60	.83	.63	.64	.65	.85	.68
11	.52	.50	.74	.68	.56	.51	.75	.67

[a]High "e" or R^2 value means the hedge is effective.

Table 4.2. Ordinary Least Squares estimates of β^*, the risk-minimizing hedge ratio.

Number of Months Prior to Contract Month	Treasury-Bill Futures				CD Futures			
	one-week	two-week	13-week (forward)	13-week (spot)	one-week	two-week	13-week (forward)	13-week (spot)
1	.90	.82	-	-	.84	.76	-	-
2	.84	.99	-	-	.71	.83	-	-
3	.58	.56	1.03	1.03	.60	.60	.93	.89
4	.92	.88	1.02	1.00	.86	.79	.90	.88
5	.88	1.05	.91	.91	.70	.81	.89	.89
6	.64	.62	1.24	1.14	.66	.67	.99	.91
7	1.02	.93	1.10	1.04	.89	.80	.96	.91
8	.94	1.12	.97	.95	.76	.89	.95	.93
9	.72	.70	1.40	1.25	.75	.76	1.12	1.00
10	1.13	1.02	1.23	1.12	1.00	.88	1.07	.99
11	.89	1.13	1.00	.94	.80	.95	.96	.89

Table 4.3. The Effectiveness of Hedging Anticipated Spot CD Positions (one-, two-, and thirteen-week hedges), using "rebuilt" R^2 to correct for autocorrelation

Number of Months	Treasury-Bill Futures				CD Futures			
Prior to Contract Month	one-week	two-week	13-week (forward)	13-week (spot)	one-week	two-week	13-week (forward)	13-week (spot)
1	.76	.78	-	-	.81	.82	-	-
2	.62	.69	-	-	.69	.73	-	-
3	.55	.49	.88	.86	.71	.68	.99	.89
4	.62	.70	.92	.81	.74	.78	.96	.84
5	.60	.65	.77	.67	.62	.63	.84	.73
6	.59	.51	.93	.79	.75	.73	.91	.76
7	.45	.62	.85	.69	.62	.66	.88	.72
8	.58	.61	.70	.58	.60	.60	.74	.61
9	.56	.48	.85	.67	.75	.75	.87	.70
10	.61	.60	.83	.63	.64	.64	.85	.67
11	.49	.50	.73	.66	.56	.51	.74	.66

Table 4.4. Generalized Least Squares estimates of β, the risk-minimizing hedge ratio

Number of Months Prior to Contract Month	Treasury-Bill Futures				CD Futures			
	one-week	two-week	13-week (forward)	13-week (spot)	one-week	two-week	13-week (forward)	13-week (spot)
1	.90	.89	-	-	.84	.82	-	-
2	.75	.85	-	-	.64	.70	-	-
3	.61	.66	1.01	1.11	.65	.64	.93	.96
4	.92	.92	1.00	.98	.86	.82	.87	.83
5	.79	.88	.84	.71	.64	.68	.82	.72
6	.64	.77	1.26	1.33	.73	.70	1.12	1.06
7	1.02	.98	1.05	.97	.89	.83	.89	.82
8	.85	.96	.95	.79	.70	.75	.87	.73
9	.82	.88	1.54	1.55	.82	.79	1.23	1.19
10	1.13	1.09	1.20	1.10	1.00	.98	1.01	.94
11	.77	1.10	.92	.79	.77	.97	.89	.77

Table 4.5. Differences in Hedging Effectiveness, $R^2_{CD} - R^2_T$ (Rebuilt R^2 Statistics)

Months prior to contract month	1 week	Hedging Length 2 weeks	13-weeks (implied rate)	13 weeks (spot)
1	.05	.05	-	-
2	.07	.04	-	-
3	.16	.19	.11	.03
4	.12	.08	.04	.03
5	.02	-.02	.07	.06
6	.16	.22	-.02	-.03
7	.03	.04	.03	.03
8	.02	-.01	.04	.03
9	.19	.27	.02	.03
10	.03	.04	.02	.04
11	.07	.01	.01	.00

introduction of the CD futures contract in 1981, Hicks had observed this quarterly decline in the effectiveness of CD cross hedges.

A possible explanation for this phenomenon is that these are the months the Treasury's quarterly refunding announcements are made. One would expect that announcements on the number of Treasury bills to be auctioned to affect the T-bill futures market more than the CD futures market. This is new information that would change expectations of future T-bill spot prices more than it would change expectations of future CD spot prices because this information is more specific to the one market than the other. If this hypothesis is true, one would expect to see substantial improvement in hedging effectiveness during these months with CD-CD futures hedge constructions. The results, however, do not lend strong support to this hypothesis. Table 4.5 shows that improvement in hedging effectiveness is not substantially greater for hedges begun during Treasury refunding months than for hedges begun in other months. Hedging effectiveness declines for both CD cross hedges and CD hedges during the months of January, April, July and October.

For the shorter-term hedging lengths, there also are exceptions to the rule of declining hedging effectiveness the further from contract maturity. Cross hedges begun three, six and nine months prior to contract maturity are less effective than hedges begun a month earlier or later. As a result, the difference in hedging effective becomes especially pronounced during these months. The beginning dates for these hedges fall in the months of March, June, September and December.

It is interesting to note that these quarterly declines in hedging effectiveness occurs only in short-term CD cross hedges and not in any CD-CD futures hedges. A separate test shows that the correlation between 90-day spot T-bills and T-bill futures also declines during these months. These observations suggest that the cause of the decline in hedging effectiveness is isolated in the T-bill futures market. One can only speculate that short-term technical factors, such as offsetting short positions, have increased significance during delivery months causing futures prices to move independently of the hedger's information set. Why the CD futures market is spared from this experience remains a mystery.

Using the implied forward price in place of the spot price in 13-week hedge constructions amplifies the difference in effectiveness between CD hedges and CD cross hedges. As can be seen from Table 4.5, when the implied rate is used, the difference in effectiveness between CD hedges and CD cross hedges becomes greater than the difference when only the spot rate is used. This increase in relative hedging effectiveness is especially pronounced for hedges started close to delivery. For example, for 13-week hedges begun 3 months prior to contract maturity, the difference in relative hedging effectiveness increases from .03 to .11 when the implied forward rate is used.

Using the implied forward price causes the rebuilt R^2 statistics to increase significantly for both CD hedges and cross hedges. Not only is the measure of hedging effectiveness altered significantly, but the risk-minimizing hedge ratios are also affected. These results suggest serious shortcomings in the practice of using the spot price as a proxy for expected future spot prices.

Tables 4.2 and 4.4 show the risk-minimizing hedge ratios for the various hedge constructions. For anticipatory hedges, these coefficients should be interpreted as the number of futures contracts that must be sold and later repurchased to provide an optimal hedge for an anticipated spot CD position of 1 million dollars. In general, for a given R^2, the higher the values for β, the less effective the hedge. A hedge construction with a high β relative to the βs of other hedge constructions means that more contracts must be used to achieve a certain level of protection. Or, in other words, a high β means it's costly to achieve a given level of protection. Tables 4.2 and 4.4 show that in virtually every case, CD hedges have lower βs than do CD cross hedges.

An alternative, non-regression, method for finding the optimal hedge ratio has been proposed by Starleaf and Langley (1983). With this method, a complete hedge is defined to be one where the expected net gain or loss from hedging is zero:

$$\text{(4-4)} \quad \text{net gain or loss} = 0 = \left(S_t - E(S_t \mid \phi_{t-k})\right) - n^*\left(F_t^{t+T} - F_{t-k}^{t+T}\right)$$

where n* is the number of contracts shorted and later repurchased or bought and later sold.

Given this definition, a value for n* can be found that will on average yield a complete hedge:

$$\text{(4-5)} \quad n^* = \frac{\Sigma[S_t - E(S_t \mid \phi_{t-k})]}{\Sigma\left(F_t^{t+T} - F_{t-k}^{t+T}\right)}$$

Instead of minimizing the sum of squared error terms as in regression, with this method the objective function is solved directly. With this method the calculations of the expected values requires special care so that positive and negative values do not cancel each other. To avoid this problem, absolute values are used except when the numerator and denominator move in opposite directions. In these cases, absolute differences between "surprises" and futures changes are used as an approximation. As one can see from equation 4-4, these calculation adjustments are consistent with the objective of the hedger.

Values for n^* were computed for each hedge construction, and the results are presented in Table 4.6. These results often differ from OLS and GLS estimates of the risk-minimizing hedge ratio. The most striking difference occurs for hedges begun 2, 5, 8, and 11 months prior to delivery. In every case during these months, n^* is greater than β_{GLS} or β_{OLS}. These months are when Treasury refunding announcements are made. During these months, futures and spot prices often move in opposite directions. Regression estimates of the optimal hedge ratio may penalize opposite price moves too much and yield misleading results.

Empirical Evidence on the Price Discovery Performance of the CD Futures Market

In this section, the main empirical results of the efficiency tests are reported. The analysis is done using daily observations for CD futures prices. The sample period is again between July, 1981, and September, 1983. The data are arranged, as in the previous section, so

Table 4.6. Optimal number of contracts, η^* hedge ratio.

Number of Months Prior to Contract Month	Treasury-Bill Futures one-week	two-week	13-week (forward)	13-week (spot)	CD Futures one-week	two-week	13-week (forward)	13-week (spot)
1	.90	.81	-	-	.77	.79	-	-
2	.86	1.07	-	-	.74	.85	-	-
3	.71	.72	1.03	.96	.67	.67	.84	.78
4	.90	.87	1.03	1.02	.80	.77	.87	.86
5	.94	1.16	1.02	1.07	.78	.93	.94	.96
6	.77	.74	1.17	1.15	.70	.66	1.03	.96
7	1.06	.96	1.14	1.12	.91	.86	.99	.97
8	.91	1.30	1.10	1.14	.86	1.06	1.12	1.13
9	.89	.83	1.44	1.32	.80	.77	1.19	1.10
10	1.10	1.04	1.34	1.30	.98	.92	1.16	1.13
11	1.10	1.46	1.06	1.05	.97	1.16	1.04	1.07

that separate regression tests of market efficiency are performed for observations on nearby and distant contracts.

Regression analysis

The efficient markets hypothesis states that all currently available and relevant information about current and future events will be reflected in current market prices. Thus, as new information about future events becomes available, expectations of future prices will change, causing changes in current prices. If new information comes to the market in the form of a random series of events, and if market prices change quickly according to revised expectations, then today's forecast revision should be uncorrelated to previous forecast revisions.

Tables 4.7 and 4.8 give the results of ordinary least squares regression estimates of equation 3-38.

$$(3\text{-}38) \quad \left(F_t^{t+T} - F_{t-1}^{t+T}\right) = a + b_1\left(F_{t-1}^{t+T} - F_{t-2}^{t+T}\right) + b_2\left(F_{t-2}^{t+T} - F_{t-3}^{t+T}\right) + \mu_t$$

The hypothesis that $F_t^{t+T} = E(S_{t+T}|\phi_t)$ implies that today's forecast revision, $F_t^{t+T} - F_{t-1}^{t+T}$, is uncorrelated with information available at time t-1. These regressions test the hypothesis that $F_t^{t+T} - F_{t-1}^{t+T}$ is orthogonal to ϕ_{t-1}.

In general, the results are consistent with the efficient markets hypothesis. However, the joint test of the null hypothesis that a $a = b_1 = b_2 = 0$ is rejected in periods 5 and 11 at a 5 percent significance level. The hypothesis that $a = b_1 = 0$ is rejected in periods 2, 5, 8, and 11, also at the 5 percent level. The failure to accept these null hypotheses is due to the marginal significance of the intercept term,

Table 4.7. Regression estimation of

$$\left(F_t^{t+T} - F_{t-1}^{t+T}\right) = a + b_1\left(F_{t-1}^{t+T} - F_{t-2}^{t+T}\right) + b_2\left(F_{t-2}^{t+T} - F_{t-3}^{t+T}\right)$$

Number of Months Prior to Contract Month	a	b_1	b_2	F^1 (b_1=b_2=0)	F^2 (a=b_1=b_2=0)	R^2
1	.031 (1.392)	-.001 (-.012)	.144 (1.843)	1.699	2.259	.020
2	.047* (2.120)	.037 (.435)	.020 (.230)	.124	1.854	.001
3	-.005 (-.255)	.059 (.777)	.074 (.979)	.800	.592	.030
4	.014 (.668)	-.036 (-.456)	.173* (2.172)	2.478	1.97	.030
5	.037 (1.964)	.116 (1.376)	.062 (.728)	1.343	2.84*	.019
6	-.004 (-.251)	.082 (1.097)	.064 (.860)	1.028	.753	.012
7	.009 (.491)	-.072 (-.893)	.159 (1.949)	2.433	1.78	.030
8	.034 (1.89)	.057 (.684)	.099 (1.181)	.980	2.35	.014
9	.003 (-.218)	.077 (1.020)	.048 (.647)	.763	.563	.009

10	.008 (.422)	-.086 (-1.015)	.172 (1.983)*	.036	1.93	.036
11	.036 (1.866)	1.193 (1.806)	.021 (.204)	1.742	2.992*	.037
12	-.004 (-.211)	-.0954 (-1.226)	.031 (.407)	.892	.605	.011

Table 4.8. Regression estimation of

$$\left(F_t^{t+T} - F_{t-1}^{t+T}\right) = a + b_1\left(F_{t-1}^{t+T} - F_{t-2}^{t+T}\right) + \mu$$

Number of Months Prior to Contract Month	a	b_1	F^1 $b_1=0$	F^2 $a=b_1=0$	R^2
1	.039 (.075)[a]	.001 (.986)	.000	1.664	.000
2	.048* (2.19)	.038 (.444)	.197	2.773*	.001
3	-.006 (-.347)	.061 (.801)	.642	.408	.004
4	.021 (1.019)	-.038 (-.483)	.233	.579	.002
5	.039* (2.097)	.124 (1.471)	2.164	4.0155*	.015
6	-.006 (-.341)	.086 (1.148)	1.317	.761	.008
7	.015 (.813)	-.083 (-1.024)	1.048	.760	.007
8	.037* (2.084)	.062 (.751)	.564	2.824	.004
9	-.004 (0.290)	.079 (1.054)	1.110	.637	.006

10	.014 (.780)	-.103 (-1.202)	1.444	.908	.010
11	.036* (1.923)	.196 (1.865)	3.479	4.515*	.037
12	-.004 (-.224)	-.098 (-1.275)	1.627	.828	.010

[a]t statistics in parentheses.

*significant at 5 percent level.

as in every case the hypotheses that $b_1 = b_2 = 0$ is not rejected.

These results imply the possibility of a systematic disturbance in the CD futures market occurring during the months of January, April, July, and October. As mentioned before, these months correspond with the Treasury's quarterly refunding announcements. The null hypothesis in both cases is accepted at a 1 percent significance level.

The results also suggest that there is no difference in efficiency between nearby and distant contracts. The results are nearly the same no matter the time distance between the observation and the delivery month. One might not have expected these results since distant contracts are so much thinner than nearby contracts. One might have expected that the arrival of new information would not be rapidly incorporated into distant contract prices because of a possible lack of competition. Although the distant contracts are thin, they are apparently competitive enough that their price discovery performance is adequate.

In sum, these results are consistent with the hypothesis that the CD futures market is adequately performing its price discovery function. The CD futures price appears to be formed by a fairly rapid reflection of new information about future events.

CHAPTER V. SUMMARY AND CONCLUSIONS

This study was initiated to examine the hedging and price discovery performance of the CD futures market. Ordinarily, futures markets adequately perform these functions, resulting in the generation of economic benefits. A futures contract is denied approval by the CFTC only if it can be demonstrated that the market would not perform these functions. If the premise that financial futures are adequately performing their hedging and price discovery functions is to serve as the basis for CFTC policy toward these markets, then it should be supported by a solid body of empirical evidence. This study of the CD futures market should, therefore, be relevant to the needs of policy makers.

Hedging Performance

Before July 1981, CD futures contracts were not traded so that banks often used other futures contracts -- usually Treasury-bill futures contracts -- as hedging instruments. A study by Hicks (1980) suggested that the effectiveness of hedging anticipated CD positions could be improved with the development of a CD futures contract. Market studies by the Chicago Mercantile Exchange, the Chicago Board of Trade and the New York Futures Exchange showed that banks (and others) would use such a contract if it existed. As a result of these studies, the CFTC granted approval of CD futures contracts on these exchanges in the spring of 1981. The expectation of all parties was that the CD futures contract would provide a vehicle for hedging short-term CDs that was more effective than Treasury-bill futures.

Hedging effectiveness should be evaluated in comparison to the objective of the hedger. With CD futures, the objective of the hedger will most often be to avoid the consequences of unwelcome surprises. The surprise will be the difference between future spot CD prices and expected spot CD prices.

In this study, the model employed to evaluate hedging performance provides estimates of the correlation between spot market surprises and changes in futures prices. If the correlation is high, one may conclude that the futures market is useful in offsetting the consequences of unanticipated changes in interest rates.

The model was used to generate measures of the effectiveness of hedging short-term CDs with CD futures. These measures were then compared to the measures generated for CD hedges constructed with T-bill futures.

The results of this study demonstrate that the CD futures market is adequately performing its hedging function. For those who anticipate positions in the spot CD market, the CD futures market almost always outperformed the T-bill futures market as a hedging vehicle for avoiding the consequences of unwelcome surprises. The difference in hedging performance is especially pronounced for hedges begun during delivery months.

The results also indicate that the choice of a proxy for the expected future spot rate can be important in evaluating hedging performance. Previous hedging studies have used the current spot rate as a proxy for future spot rates. For hedging lengths of one or two weeks, this may not be an unreasonable assumption, but for longer-term hedges, this assumption becomes less reasonable. These result shows that when the implied forward rate is used as a proxy for the expected spot rate, hedging effectiveness measures are improved significantly.

Before the introduction of CD futures, Hicks (1980) had observed a quarterly decline in the effectiveness of CD-T-bill futures hedge constructions. These declines correspond with the Treasury's quarterly refunding announcements. This observation led some to suggest that the introduction of CD futures would improve hedging performance during these months. The reasoning behind this hypothesis was that Treasury refunding announcements would change expectations of future T-bill spot prices more than they would change expectations of future CD spot prices because this information is more specific to the one market than the other.

If the hypothesis is true, one would expect to see substantial improvement in hedging effectiveness during these months with CD-CD futures hedge constructions. The results, however, do not lend strong support to this hypothesis. Hedging effectiveness declines quarterly for CD-CD futures hedge constructions also, leaving the overall improvement in hedging effectiveness about the same as for hedges begun in other months.

These results do, however, confirm the conventional wisdom that "traditional" hedges outperform cross hedges. The difference in hedging effectiveness between these two types of hedge constructions can be accounted for by differences in the instruments underlying each futures contract. Although T-bills and CDs are similar in many respects, they differ in some important ways. One represents public debt, the other private; one has no default risk, the other does. The underlying instruments are different enough that the futures prices for each will be responding to different information sets.

Price Discovery Performance

The second economic function of a futures market is price discovery. If the futures price is formed by fully reflecting all available information, the market is said to be efficient. Efficient markets ensure that the market is performing its price discovery function.

Using a test procedure similar to one used by Hansen and Hodrick (1980), a direct test of the weak-form efficient markets hypothesis can be applied to the CD futures market. A "direct" test uses the actual futures prices as opposed to "indirect" tests which compare futures market forecasts with those of forecasting models or trading systems. Berger (1982) has shown that direct tests reject the null hypothesis more frequently than indirect tests when the alternative hypothesis is true, i.e., direct tests are more powerful than indirect tests.

The test used in this study involves estimating regressions of forecast revisions on a constant and the two most recent forecast revisions. The equation may be expressed as:

$$(5.1)\quad \left(F_{T}^{t+T} - F_{t-1}^{t+T}\right) = a+b_1\left(F_{t-1}^{t+T} - F_{t-2}^{t+T}\right) + b_2\left(F_{t-2}^{t+T} - F_{t-3}^{t+T}\right) + \mu_t$$

The operational null hypothesis of weak-form efficient markets in a risk-neutral world can be expressed as:

$$H_0:\quad a = b_1 = b_2 = 0$$

To test the joint hypothesis that all coefficients are zero, the F-statistics will be appropriate.

Results of these tests of the weak-form efficient markets hypothesis indicate that new information is quickly incorporated into market prices. Current forecast revisions are uncorrelated with recent forecast revisions. This is the result one would expect if the market is efficient and new information comes to the market as a random series of events. A surprising result was uncovered in that forecast revisions appeared to differ systematically during the months of January, April, July and October. These months correspond with the Treasury's quarterly refunding announcements. The deviations from the efficient markets hypothesis were, however, small. These results are consistent with the hypothesis that the CD futures market is adequately performing its price discovery function.

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APPENDIX A. SPECIFICATIONS OF CD AND T-BILL FUTURES CONTRACTS

SPECIFICATIONS FOR THREE-MONTH DOMESTIC CERTIFICATES OF DEPOSIT FUTURES CONTRACTS TRADED ON THE INTERNATIONAL MONETARY MARKET

SCOPE OF CHAPTER—This chapter is limited in application to contract specifications of Three-Month Domestic Certificates of Deposit futures which are open for trading and delivery on the International Monetary Market, a Division of the Chicago Mercantile Exchange. The procedures for trading, clearing, delivery, settlement and any other matters not specifically contained herein shall be governed by the rules of the Chicago Mercantile Exchange.

COMMODITY SPECIFICATIONS—Each futures contract shall be for a Domestic Certificate of Deposit having a principal value of $1,000,000 with a three-month maturity.

TRADING MONTHS—March, June, September, December

TICKER SYMBOL—DC

TRADING HOURS—8:00 a.m. to 2:00 p.m.

PRICE INCREMENTS—Bids and offers shall be quoted in terms of the I.M.M. Index, 100.00 minus yield on an annual basis for a 360-day year. (A deposit rate of 7.20% shall be quoted as 92.80.) Minimum fluctuations of the I.M.M. Index shall be in multiples of .01 ($25.00).

NORMAL DAILY PRICE LIMITS—There shall be no trading at a level more than 0.80 (80 basis points) I.M.M. Index points above or below the preceding day's settlement price except when the expanded daily price limit schedule goes into effect and on the last day of trading when there shall be no limit.

EXPANDED DAILY PRICE LIMITS—Whenever on two successive days any contract month settles at the normal daily limit in the same direction (not necessarily the same contract month on both days) an expanded daily limit schedule shall go into effect as follows:

1. The third day's daily limit in all contract months shall be 150% of the normal daily limit.

2. If any contract month settles at its expanded daily limit on the third day in the same direction, then the fourth day's expanded daily limit and each successive day thereafter, shall be 200% of the normal daily limit, so long as any contract month settles at its expanded daily limit.

3. Whenever the foregoing daily limit schedule is in effect and no contract month settles at the limit in the same direction which initiated or maintained the expanded schedule, then the normal daily limit shall be reinstated on the following day.

SETTLEMENT PRICE—The Settlement Price may be outside of the day's High/Low range, and/or may be different from the midpoint of the Closing Range, per C.M.E. Rule 813.

TERMINATION OF FUTURES TRADING — Futures trading shall terminate on the business day immediately preceding the last delivery day of the contract month.

DELIVERY DAYS—Delivery shall be made on any business day that is not a bank holiday in either New York or Chicago, and in the period beginning on the 15th day of the contract month, and ending on the last business day of the contract month.

APPROVED DELIVERY BANKS—On the second business day preceding the 15th calendar day of each month, the I.M.M. staff will update a list of Domestic Certificates of Deposit accepted as good delivery. This list will be composed of those Domestic Certificates of Deposit that are considered by the cash market to be of the highest liquidity, lowest credit risk and which trade at identical yields. The list will be formed by selecting a random sample of at least 7 dealers from a list of at least 10 dealers who actively participate in the Domestic Certificate of Deposit market. The bank names that are common to at least five lists in the sample and have agreed to be deliverable on the contract will comprise the list of deliverable Domestic Certificate of Deposit issues.

DELIVERABLE ISSUES—Any Domestic Certificate of Deposit meeting the following conditions shall constitute a deliverable CD.

1. having a fixed maturity value* not less than $1,000,000 and not greater than $1,200,000,

2. having no interest payments between the delivery date and maturity date,

3. maturity not before the 16th of the month three months after the spot month nor after the last day of the month three months after the spot month,

4. maturing on a business day that is not a banking holiday in either New York or Chicago; and

5. having no more than 185 days accrued interest payable at maturity.

*Maturity value on discount Domestic Certificates of Deposit means principal value. Maturity value on add-on Domestic Certificates of Deposit means principal plus interest payable at maturity.

SELLER'S DUTIES—The clearing member representing a customer making delivery in liquidation of his position, shall present to the Clearing House by 2:00 p.m., one business day before delivery day, a Seller's Delivery Commitment completed in full. If such commitment is received later than 2:00 p.m. on the business day prior to the last delivery but not later than 9:00 a.m. on the last delivery day, seller's clearing member shall be assessed a fine on a per contract basis, the amount to be determined by the Board. Any papers received subsequent to 9:00 a.m. on the last delivery day shall constitute the seller's failure to perform and be acted upon in accordance with Rule 3806.

Before 12:00 noon (Chicago time) on the delivery date, Seller's Clearing Member shall deliver a Domestic Certificate of Deposit of an Approved Delivery Bank, satisfying the conditions of Rule 3803-D, to a New York City bank registered with the Exchange and a member of the Federal Reserve System selected by the buyer.

BUYER'S DUTIES—Upon notification of delivery by the Clearing House, the clearing member representing the buyer shall deliver to the Clearing House by 5:00 p.m. (Chicago time) on the day before the delivery date, a Buyer's Delivery Commitment that includes: the buyer's name and account number, and the name of a New York City bank registered with the Exchange and a member of the Federal Reserve System to which the delivery unit should be transferred. The clearing member representing the buyer shall, by 12:45 p.m. (Chicago time) by payment against delivery on the day of delivery, present to the seller's clearing member's bank or its designated agent a wire transfer of Federal funds for the net invoicing price.

PAR DELIVERY—A delivery unit shall be a Domestic Certificate of Deposit of an approved delivery bank satisfying the conditions of 3803-D.

The following formula shall be used to calculate the net invoicing price:

$$(\text{maturity value}^{*}) \div \left[1 + (\text{F yield}^{**}) \frac{\text{days to maturity}}{360}\right]$$

* Maturity value on discount Domestic Certificates of Deposit means principal value. Maturity value on add-on Domestic Certificates of Deposit means principal plus interest payable at maturity.

**The F yield is the difference between 100.00 and the I M M Index at settlement on the day before delivery day, expressed in decimals. F yield = (100.00 - F index) × 0.01.

DELIVERY POINTS—Delivery shall be made to a New York City bank, registered with the Exchange and a member of the Federal Reserve System, specified by the buyer's clearing member. All banks selected by the buyer and by the seller to effectuate delivery must be members of the Federal Reserve System.

DISCRETIONARY POSITION LIMITS—The Board may in its sole and complete discretion impose limits upon an individual or upon related accounts.

CONTRACT MODIFICATION—Specifications shall be fixed as of the first day of trading of a contract except that all deliveries must conform to government regulations in force at the time of delivery. If any U.S. governmental agency or body issues an order, ruling, directive or law pertaining to the trading or delivery of Domestic Certificates of Deposit, such order, ruling, directive or law shall be construed to take precedence and become part of these rules, and all open and new contracts shall be subject to such government orders.

EMERGENCIES, ACTS OF GOD, ACTS OF GOVERNMENT—If delivery or acceptance or any precondition or requirement of either is prevented by strike, fire, accident, action of government or act of God, the seller or buyer shall immediately notify the Exchange President. If the President determines that emergency action may be necessary, he shall call a special meeting of the Board of Governors and arrange for the presentation of evidence respecting the emergency condition. If the Board determines that an emergency exists, it shall take such action as it deems necessary under the circumstances and its decision shall be binding upon all parties to the contract. For example, and without limiting the Board's power, it may: take action in accordance with Rule 3806; extend delivery dates; and designate alternate approved banks in the event of conditions interfering with the normal operations of approved facilities.

In the event that the Board of Governors or Business Conduct Committee determines that there exists a shortage of deliverable Domestic Certificates of Deposit, it may upon a two-thirds vote of the members present or upon a two-thirds vote of the members who respond to a poll take such action as may in the Board's or Committee's sole discretion appear necessary to prevent, correct, or alleviate the condition. Without limiting the foregoing, the Board or Committee may: (1) designate as deliverable Certificates of Deposit of banks not on the Approved Bank List and (2) determine a cash settlement based on the current cash value of a 3-month Certificate of Deposit as determined by using the current cash market yield curve on the last day of trading.

FAILURE TO PERFORM—If the clearing member with a delivery commitment fails to perform all acts required by this chapter, then that clearing member shall be deemed as failing to perform which may be punishable as a major violation. A clearing member failing to perform shall be liable to the clearing member to which it was matched on the failing transaction for any loss sustained, taking into account the settlement price, interest earnings foregone, and such other factors as it deems appropriate. The Board may also assess such penalties as it deems appropriate in addition to damages.

SPECIFICATIONS FOR U.S. 90-DAY TREASURY BILL FUTURES CONTRACTS TRADED ON THE INTERNATIONAL MONETARY MARKET

SCOPE OF CHAPTER—This chapter is limited in application to contract specifications of U.S. Treasury Bill futures which are open for trading and delivery on the International Monetary Market, a Division of the Chicago Mercantile Exchange. The procedure for trading, clearing, delivery, settlement and any other matters not specifically contained herein shall be governed by the rules of the Chicago Mercantile Exchange.

COMMODITY SPECIFICTIONS—Each futures contract shall be for 3-month (13 week) U.S. Treasury bills having a face value at maturity of $1,000,000.

TRADING MONTHS—March, June, September, December. Effective July 2, 1980, a new quarterly cycle consisting of January, April, July and October was listed for trading as "regular" contracts months in addition to the quarterly cycle of March, June, September and December.

TICKER SYMBOL—TB

TRADING HOURS—8:00 a.m. - 2:00 p.m.

PRICE INCREMENTS—Prices shall be quoted in terms of the I.M.M. index. (Example: A T-bill yield of 5.20 shall be quoted as 94.80)

The I.M.M. index is the difference between the actual T-bill yield and 100.00.

A *T-bill yield, or bank discount rate, is the difference between the face value of a bill and its market* value on an annualized basis.

Minimum price fluctuations of the I.M.M. index shall be in multiples of .01 ($25.00) The minimum fluctuation is equal to one basis point.

DAILY PRICE RANGE—*There shall be no trading at a price more than .60 (60 basis points) above or* below the preceding day's settlement price except when the expanded daily price limit schedule goes into effect, and on the last day of trading when there shall be no limit.

EXPANDED DAILY PRICE LIMITS—Whenever on two successive days any contract month settles at the normal daily price limit in the same direction (not necessarily the same contract month on both days) an expanded daily price limit schedule shall go into effect as follows:

1. The third day's daily price limit in all contract months shall be 150% of the normal daily price limit.
2. If any contract month settles at its expanded daily price limit on the third day in the same direction, then the fourth day's expanded daily price limit and each successive day thereafter, shall be 200% of the normal daily price limit, so long as any contract month settles at its expanded daily price limit.
3. Whenever the foregoing daily price limit schedule is in effect and no contract month settles at the price limit in the same direction which initiated or maintained the expanded schedule, then the normal daily price limit shall be reinstated on the following day.

SETTLEMENT PRICE—Effective March 27, 1981: The Settlement Price may be outside of the day's High/Low range, and/or may be different from the midpoint of the Closing Range, per C.M.E. Rule 813.

TERMINATION OF FUTURES TRADING—Futures trading shall terminate on the second business day following the Federal Reserve 3-month (13-week) Treasury-bill auction of the third week of the delivery month. In the event that no auction is conducted, trading shall terminate on the third Wednesday of the contract month, unless that day is an Exchange holiday. In such instance, trading shall terminate on the next business day. For purposes of the rule, the "third week of the delivery month" shall mean the week commencing on the third Monday of the delivery month. Effective with the December 1980 Futures Contract futures trading in the spot month shall terminate on the business day immediately preceding the first delivery day.

PAR DELIVERY—A delivery unit shall be composed of a United States Treasury bill(s) maturing 90 days hence (effective December 1980 Futures Contract: maturing 90 days from the first delivery day) with a face value of $1,000,000 at maturity.

DELIVERY POINTS—Delivery shall be made to a Chicago (effective March 1981 Futures Contract: or New York) bank, registered with the Exchange and a member of the Federal Reserve System, specified by the buyer's clearing member. All banks selected by the buyer and by the seller to effectuate delivery must be members of the Federal Reserve System.

DELIVERY DAYS—Delivery shall be made on the business day following the last day of trading, unless that day is an Exchange or Illinois bank holiday, in which case delivery shall be on the next business day common to the Exchange and Illinois banks. Effective with the December 1980 Futures Contract: Delivery shall be made on the three business days beginning with the day of issue of 13-week Treasury bills in the third week of the spot month. For purposes of the rule, the "third week of the spot month" shall mean the week commencing on the third Monday of the spot month. Effective June 1983 Futures Contract: Delivery shall be made on three successive business days. The first delivery day shall be on the first day of the spot month on which a 13-week Treasury bill is issued and a one-year Treasury bill has 13 weeks remaining to maturity.

REGISTERED BANKS AND OTHER FACILITIES—The Board shall establish such requirements and pre-conditions for registration as a facility for the delivery of Treasury bills as it deems necessary.

SUBSTITUTIONS—At the seller's option, a delivery unit may be composed of U.S. Treasury bills bearing maturities of 91 or 92 days (effective December 1980 Futures Contract: bearing maturities of 91 or 92 days from the first delivery day). All bills in a delivery unit must bear uniform maturity dates.

The following formula shall be used to calculate the value of the delivery unit:

$$\$1{,}000{,}000 - \frac{(\text{days from issue date to maturity date} \times \text{T-bill yield}^{*} \times \$1{,}000{,}000)}{360} = \text{dollar value}$$

*For the purpose of this formula, the T-bill yield shall be the difference between the I.M.M. index at settlement on the last day of trading and 100.00, multiplied by 0.01. For example, a settlement price of 95.00 would create a T-bill yield of (100.00 − 95.00) × 0.01 = .0500.

PAYMENT—The Clearing House shall monitor the delivery procedure to ensure proper transfer of Treasury bills and direct payment by the buyer to the seller. Payment shall be made on the basis of par value ($1,000,000) minus yield, expressed in dollars, as determined by the settling price of the futures contract, discounted from the final settlement date to maturity date on a 360-day year.

COSTS OF DELIVERY—All costs incurred in effectuating delivery shall be borne by the seller.

SELLER'S DUTIES—The clearing member representing the seller shall deliver to the Exchange Clearing House by 12 noon (Chicago time) on the last day of trading a seller's delivery commitment indicating a Chicago (effective March 1981 Futures Contract: or New York) bank, registered with the Exchange and a member of the Federal Reserve System, and the name of the account from which the delivery unit will be transferred. By 12:45 p.m. (Chicago time) on the day of delivery, the seller shall deliver to a Chicago (effective March 1981 Futures Contract: or New York) bank, registered with the Exchange and a member of the Federal Reserve System, selected by the buyer, a United States Treasury bill(s) maturing in 90 days (effective December 1980 Futures Contract: maturing 90 days from the first delivery day), with a face value at maturity of $1,000,000.

BUYER'S DUTIES—The clearing member representing the buyer shall deliver to the Clearing House by 12 noon (Chicago time) on the last day of trading a buyer's delivery commitment including the buyer's name and account number, and the name of a Chicago (effective March 1981 Futures Contract: or New York) bank, registered with the Exchange and a member of the Federal Reserve System, to which the delivery unit should be transferred, and, by 11:00 a.m. (Chicago time) on the day of delivery shall present to the selling clearing member's bank or its designated agent a wire transfer of Federal funds for the net invoicing price.

ACCUMULATION OF POSITIONS—The positions of all accounts owned or controlled by a person or persons acting in concert or in which such person or persons have a proprietary or beneficial interest shall be cumulated. The Board may impose individual position limits for any such account or accounts as it deems appropriate.

CONTRACT MODIFICATION—Specifications shall be fixed as of the first day of trading of a contract except that all deliveries must conform to government regulations in force at the time of delivery. If any U.S. governmental agency or body issues an order, ruling, directive or law pertaining to the trading, government auction, or delivery of U.S. Treasury bills, such order, ruling, directive or law shall be construed to take precedence and become part of these rules, and all open and new contracts shall be subject to such government orders.

FAILURE TO PERFORM—If the clearing member with a delivery commitment fails to perform all acts required by this chapter, then that clearing member shall be deemed in default, which may be punishable as a major violation. A clearing member in default shall be liable to the clearing member to which it was matched on the defaulted transaction for any loss sustained. The President shall determine and assess losses sustained, taking into account the settling price, interest earnings foregone, and such other factors as he deemed appropriate. The President may also assess such penalties as he deemed appropriate in addition to damages.

EMERGENCIES, ACTS OF GOD, ACTS OF GOVERNMENT—If delivery or acceptance or any precondition or requirement of either is prevented by strike, fire, accident, action of government or act of God, the seller or buyer shall immediately notify the Exchange President. If the President determines that emergency action may be necessary, he shall call a special meeting of the Board of Governors and arrange for the presentation of evidence respecting the emergency condition. If the Board determines that an emergency exists, it shall take such action as it deems necessary under the circumstances and its decision shall be binding upon all parties to the contract. For example, and without limiting the Board's power, it may: take action in accordance with Rule 3207; extend delivery dates; and designate alternate delivery points in the event of conditions interfering with the normal operations of approved facilities.

EFFECTIVE DECEMBER 1980 FUTURES CONTRACT—In the event that the Board of Governors or Business Conduct Committee determines that there exists a shortage of deliverable 13-week U.S. Treasury bills, it may upon a two-thirds vote of the members present or upon a two-thirds vote of the members who respond to a poll take such action as may in the Board's or Committee's sole discretion appear necessary to prevent, correct, or alleviate the condition. Without limiting the foregoing, the Board or Committee may: (1) designate as deliverable any specified U.S. Treasury bill of a maturity other than or in addition to the maturity specified above and otherwise meeting the specifications and requirements stated in the rule of "Commodity Specifications"; (2) determine a cash settlement based on the current cash value of a three-month U.S. Treasury bill as determined by using the current cash market yield curve for U.S. Treasury securities on the last day of trading.

APPENDIX B. MEAN SQUARED ERRORS FOR REGRESSIONS ESTIMATING THE EFFECTIVENESS OF HEDGING ANTICIPATED SPOT CD POSITIONS

Table B1. Mean Squared Errors for Regressions Estimating the Effectiveness of Hedging Anticipated Spot CD Positions. Not corrected for autocorrelation

Number of Months Prior to Contract Month	Treasury-Bill Futures				CD Futures			
	one-week	two-week	13-week (forward)	13-week (spot)	one-week	two-week	13-week (forward)	13-week (spot)
1	.060	.112	-	-	.048	.091	-	-
2	.073	.188	-	-	.060	.164	-	-
3	.052	.152	.638	.665	.033	.099	.055	.524
4	.097	.150	.403	1.021	.065	.113	.198	.850
5	.077	.212	.607	.899	.074	.223	.429	.736
6	.047	.142	.343	.859	.028	.082	.351	1.002
7	.104	.192	.704	1.614	.097	.174	.551	1.424
8	.082	.241	.827	1.183	.077	.243	.679	1.067
9	.050	.148	.643	1.337	.027	.076	.594	1.301
10	.111	.206	.889	2.104	.101	.184	.758	1.842
11	.093	.279	.739	.857	.084	.276	.713	.888

Table B2. Mean Squared Errors for Regressions Estimating the Effectiveness of Hedging Anticipated Spot CD Positions. Corrected for autocorrelation

Number of Months Prior to Contract Month	Treasury-Bill Futures				CD Futures			
	one-week	two-week	13-week (forward)	13-week (spot)	one-week	two-week	13-week (forward)	13-week (spot)
1	.056	.106	-	-	.045	.088	-	-
2	.071	.187	-	-	.057	.106	-	-
3	.049	.148	.572	.650	.32	.094	.045	.499
4	.092	.144	.380	.965	.061	.108	.183	.815
5	.075	.211	.591	.952	.071	.222	.414	.786
6	.048	.142	.323	.814	.027	.078	.395	1.034
7	.13	.182	.675	1.41	.09	.164	.547	1.373
8	.079	.235	.785	1.44	.074	.241	.675	1.111
9	.048	.151	.647	1.430	.027	.071	.570	1.313
10	.103	.195	.839	1.98	.095	.176	.729	1.80
11	.089	.257	.691	.834	.078	.252	.666	.842